Wood Turtle (*Glyptemys insculpta*)
Conservation Plan for Minnesota

Cover Images

Top left, bottom: Gaea Crozier, Minnesota Department of Natural Resources
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Minnesota Wood Turtle Conservation Plan Finalized July 2020

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The Nongame Wildlife Program would like to thank all who have contributed their time and expertise to the development of this Wood Turtle Conservation Plan for Minnesota. In particular, we would like to thank the members of the Wood Turtle Planning Team, Northeast Work Group, and Southeast Work Group for the large amount of time that members contributed to this project and to EOR for their outstanding facilitation of this process.

1. EXECUTIVE SUMMARY

The Wood Turtle (*Glyptemys insculpta*) is a state-threatened species in Minnesota and was identified in Minnesota's Wildlife Action Plan (2015-25) as a species in need of a statewide management plan. This document, the Minnesota Wood Turtle Conservation Plan, identifies issues, 10-year goals, prioritized strategies, and targeted implementation activities. The purpose of this plan is to identify strategies to start moving the species toward recovery.

The Minnesota Department of Natural Resources (MNDNR) Nongame Wildlife Program formed a Wood Turtle Planning Team composed of biologists with Wood Turtle expertise to guide development of the conservation plan. The MNDNR also coordinated a Northeast Work Group and a Southeast Work Group to address region-specific implementation planning and prioritization for northeast (including central) and southeast Wood Turtle populations. Emmons & Olivier Resources, Inc. (EOR) was contracted to coordinate the plan development process and write the plan with regular input meetings and feedback from the Planning Team.

The Planning Team established an overarching conservation goal for the Wood Turtle in Minnesota:

Conservation Goal:

To maintain and enhance Wood Turtle populations throughout their range in Minnesota with the goal of sustaining viable populations.

The Planning Team identified five issues affecting the Conservation Goal: 1) habitat, 2) adult mortality, removal, and sub-lethal impacts, 3) juvenile recruitment, 4) knowledge gaps, and 5) partnerships. The Planning Team subsequently developed broad, statewide 10-year goals that address each issue, with specific strategies and sub-strategies to progress toward the 10-year goals.

Regional Work Groups used the strategies and sub-strategies developed by the Planning Team to detail region-specific targeted implementation activities, milestones, tracking metrics, prioritization, and target start dates for each sub-strategy. An Implementation Plan summarizing this information was developed collaboratively by the Planning Team and Work Groups. It will be the primary means of planning, implementing, and tracking the strategies and activities identified in the plan.

Tracking performance toward targets is an important step to the Implementation Plan. Performance toward targets will be assessed every two years by documenting completed activities. After five years, work to date will be evaluated with potential for re-prioritization, timeline adjustment, and additional activities.

Location information pertaining to threatened and endangered species is very sensitive. The location data for rare species identified under Minnesota's Endangered Species Law (Minnesota Statute 84.0895) are considered non-public data under M.S. 84.0872 and should not be duplicated, publicized, or shared with others.

2. INTRODUCTION AND BACKGROUND INFORMATION

Scientific name:	*Glyptemys insculpta*
Synonym:	*Clemmys insculpta*
Common name:	Wood Turtle
Category:	Reptile
Family:	Emydidae
NatureServe global status:	G3, vulnerable
IUCN global status:	Endangered
NatureServe state status:	S2, imperiled
CITES protection:	Appendix II
Federal Status	None
State legal status:	State threatened
Minnesota Rules:	Chapter 6134, listed Wood Turtle as “MN threatened” since 1984
Legal citation:	Minnesota Statute 84.0895

2.1. CONSERVATION PLAN OBJECTIVE

The Minnesota Wood Turtle Conservation Plan was developed to identify conservation strategies for the Wood Turtle in Minnesota. Minnesota’s Wildlife Action Plan (2015-25) identified the Wood Turtle as a species in need of a statewide management plan. The Minnesota Department of Natural Resources (MNDNR) Nongame Wildlife Program formed a Planning Team composed of biologists with Wood Turtle expertise to develop the plan. The Conservation Plan identifies issues, 10-year goals, prioritized conservation strategies, and targeted implementation activities. This plan is different from a recovery plan in that it does not identify targets for recovery and delisting of the Wood Turtle. Rather the strategies identified in the Conservation Plan establish priorities for Wood Turtle conservation, will enhance our knowledge of turtle needs, and can be used to inform a future recovery plan if necessary.

2.2. SPECIES DESCRIPTION

The Wood Turtle is a medium-sized turtle with an adult carapace (upper shell) length typically in the range of 14–20 centimeters (Moriarty and Hall 2014, Powell et al. 2016). Observations of adults measuring 25 centimeters and above have been reported in northeastern Minnesota populations (Naber and Majeski 2010, Moriarty and Hall 2014). The Wood Turtle is distinguished by its broad, rugged carapace with raised, irregularly shaped pyramidal scutes (epidermal plates forming the upper and lower shells) and a central keel. Carapace color varies from brown to gray to tan; scutes of some individuals occasionally include yellow rays arranged in a sunburst pattern. The plastron (lower shell) is yellow with black blotches on the outer part of each scute. Dorsal skin coloring is brown and the underside of the neck, throat, and forelegs are generally yellow in Minnesota populations; coloration varies from yellow to orange to red across the Wood Turtle range. Hatchlings are drab, while juveniles may be colorful. Hatchling shells are circular, nearly flat, and are greenish-gray in color. Differences in appearance between adult sexes include size, coloring, and shape. Males are generally 7–10% larger than females with brighter coloring, concave plastrons, and longer, thicker tails.

2.3. STATUS, DISTRIBUTION, AND TRENDS ACROSS RANGE

2.3.1 Status

Though the Wood Turtle is not a federally listed species, it is widely considered a species at risk and is under consideration for federal listing in 2023. The Wood Turtle is designated as globally endangered by the International Union for Conservation of Nature (IUCN) (van Dijk and Harding 2011). It is ranked as vulnerable both globally (G3), and nationally (N3) in the United States (updated 2010) and Canada (updated 2016) (NatureServe 2019). Of the 22 subnational jurisdictions within the Wood Turtle range, it is ranked as imperiled in seven and critically imperiled in two (**Table 1**; NatureServe 2019). International trade of the Wood Turtle is legal but strictly regulated according to Appendix II of the Convention on International Trade in Endangered Species (CITES) (CITES 2017).

Table 1: Wood Turtle subnational conservation ranks (NatureServe 2019) and legal status

Jurisdiction	NatureServe S-Rank	Legal Status
District of Columbia	SH - Possibly Extirpated	Not Listed
Iowa	S1 - Critically Imperiled	Endangered
Ohio*	S1 - Critically Imperiled	Not Listed
Michigan	S2 - Imperiled	Special Concern
Minnesota	S2 - Imperiled	Threatened
New Jersey	S2 - Imperiled	Threatened
Nova Scotia	S2 - Imperiled	Threatened
Ontario	S2 - Imperiled	Endangered
Quebec	S2 - Imperiled	Threatened
Rhode Island	S2 - Imperiled	Species of Concern
Virginia	S2 - Imperiled	Threatened
New Brunswick	S2S3 - Imperiled/Vulnerable	Threatened
Connecticut	S3 - Vulnerable	Special Concern
Massachusetts	S3 - Vulnerable	Special Concern
New Hampshire	S3 - Vulnerable	Special Concern
New York	S3 - Vulnerable	Special Concern
Vermont	S3 - Vulnerable	Special Concern
West Virginia	S3 - Vulnerable	Special Concern
Wisconsin	S3 - Vulnerable	Threatened
Pennsylvania	S3S4 - Vulnerable/Apparently Secure	Not Listed
Maine	S4 - Apparently Secure	Special Concern
Maryland	S4 - Apparently Secure	Not Listed

* *The Wood Turtle is not considered native in Ohio and is known only from a couple of specimens (ODNR 2019).*

2.3.2 Distribution

Wood Turtles occur in 17 states and four provinces within the eastern United States and Canada, with recent isolated observations in the District of Columbia (District Department of the Environment 2015). The distribution ranges northeast to southwest along the Atlantic coast from Nova Scotia and New Brunswick to Maryland, Virginia, and West Virginia, with the range extending west to eastern Minnesota and northeastern Iowa (**Figure 1**; NatureServe 2019). Though the distribution covers a large area, the known area of occupancy is discontinuous and is likely to be much smaller than implied by the map (Environment Canada 2016). Wood Turtles are limited to rivers and streams with sand/gravel/cobble substrates, and Wood Turtle occupancy of suitable habitat is limited by historic and current land use practices.

Typical Wood Turtle habitat along a sandy streambank. J. Naber

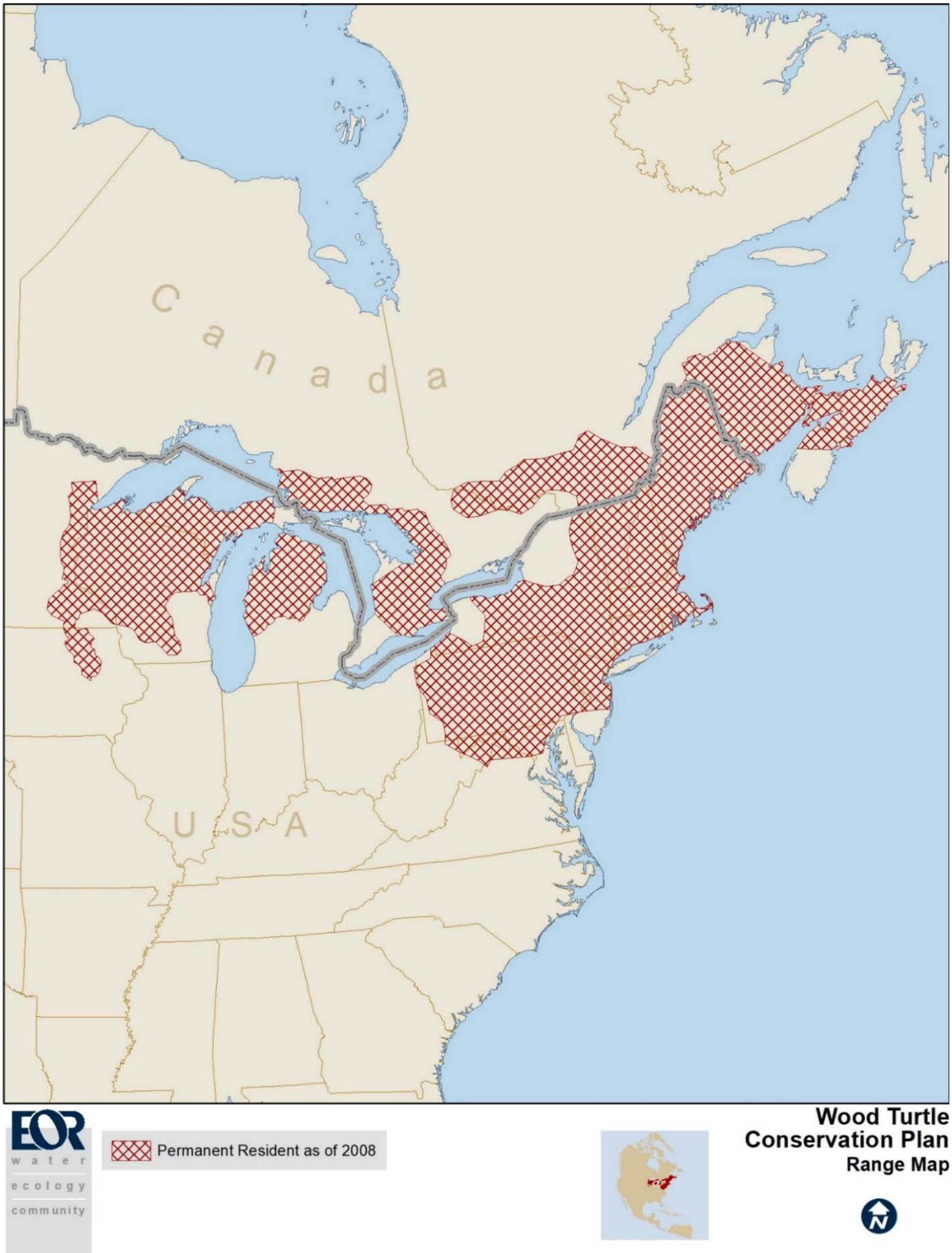


Figure 1. Global Wood Turtle distribution (NatureServe 2008, MNDNR 2018).

2.3.3 Trends

Generally, Wood Turtle populations are considered in decline throughout their range (Bowen and Gillingham 2004, van Dijk and Harding 2011), although quantitative population trends are limited to a few local populations. Most current populations are considered small, isolated, and at risk of extirpation. In Iowa, the Wood Turtle population is small and lacks recruitment, but is relatively genetically diverse and did not show evidence of bottleneck effect or inbreeding (Spradling et al. 2010). Population declines at three rivers in Michigan were inferred from genetic analyses based on effective breeding size, though the study detected no evidence of bottleneck effect and little evidence of inbreeding (Willoughby et al. 2013). Conversely, the same Michigan population increased by an average of 2–3% annually based on estimates from an 18-year mark-recapture study (Schneider at al. 2018). These studies of the same population using different methods illustrate the challenge of documenting long-term trends in species with delayed reproductive maturity such as the Wood Turtle. In Canada, the number of adults is estimated to be declining at a rate of >10% in three generations (COSEWIC 2007). Of 13 stream populations assessed in Canada, two remained stable and 11 exhibited declines based on quantitative analysis and expert opinion (Environment Canada 2016). No estimates of total abundance in the United States exist; the Canadian Wood Turtle population is estimated between 6,000 and 12,000 individuals (COSEWIC 2007).

Recently hatched Wood Turtle traveling across sandy streambank. MN DNR.

2.4. STATUS, DISTRIBUTION, AND TRENDS ACROSS RANGE IN MINNESOTA

2.4.1 Status

The Wood Turtle was designated as a threatened species in Minnesota in 1984. It is legally protected under Minnesota's Threatened and Endangered Species statute (84.0895) and is a Species in Greatest Conservation Need in the state. The Wood Turtle is also a U.S. Forest Service Regional Forester Sensitive Species within its range in Minnesota (USFS 2004).

2.4.2 Distribution

Within Minnesota, the Wood Turtle's range covers the eastern portion of the state (**Figure 2**). Historical information on Wood Turtle distribution in the state is lacking. Observations of Wood Turtles are recorded in 16 counties, with populations primarily concentrated in the northeast within the Northeast D River watershed (northeast region) and in the southeast within the Southeast B, Southeast C, and Southeast A river drainages (southeast region) (Moriarty and Hall 2014). There are four main populations of Wood Turtles in the northeast region and one main population in the southeast region. Wood Turtle populations within Minnesota extend across state boundaries, with populations shared by Wisconsin in the northeast and Iowa in the southeast (LeClere 2013). Genetic data suggest that Wood Turtles in the Southeast B River are genetically distinct between Minnesota and Iowa (Spradling et al. 2010); however, MNDNR has monitoring data showing that individuals in the Southeast C River drainage area do travel between Minnesota and Iowa. The Conservation Plan is considering the northeast and southeast regions separately due to the different needs of populations based on regional land use and respective population sizes.

2.4.3 Trends

Records of Wood Turtle occurrence in Minnesota date back to the 1930s based on reports included in the Minnesota Natural Heritage database, with formal surveys first initiated in the 1980s by the MNDNR (Ewert 1984). The largest concentration of Wood Turtle populations occurs in the northeast region, whereas the southeast populations are comparatively small (Hamady and Hall 2011). Information is lacking on populations within the central part of the state.

Population trends for Wood Turtles in Minnesota indicate reason for concern. Observational data for some populations show a concerning decrease in the number of turtles being caught during surveys. Some populations are dominated by older adult turtles with little evidence of juvenile recruitment, suggesting that these populations may be declining. Overall, populations are generally small, isolated, and at risk for extirpation.

Limited population trends exist for the state, but recent efforts quantified trends for one population. Changes in a population in the northeast were examined by comparing surveys conducted in 1990 and 2015, analyzing population monitoring data from 1997–2014, and performing a population reconstruction on almost 30 years of mark-recapture data (Cochrane et al. 2018; Moen et al. 2017; Berkeland et al. 2019). The study found no significant difference in relative abundance, adult sex ratio, juvenile-adult ratio, or mean body size between 1990 and 2015, and the population growth rate was stable from 1997–2014 (Cochrane et al. 2018). The population reconstruction suggests that the population has been relatively stable over the past 30 years (Moen et al. 2018, Berkeland et al. 2019), but it also indicates that there has been a declining population growth rate from 2006–2017 compared to 1990–2005 (Cochrane et al. 2018).

Measuring a very old male Wood Turtle found in northeast Minnesota. J. Naber

Of particular concern are monitoring data from the same population from 2016–2018 which indicate a substantial decrease in the number of individuals at eight monitoring sites coinciding with a large number of dead turtles of unknown cause found at the same sites (Berkeland et al. 2019, Crozier 2020). The estimated abundance at the eight monitoring sites was 247 individuals in 2016, and this estimate declined to 88 in 2018. Population modeling indicates that adult survival needs to be very high (about 95–97%) to sustain a stable population (Moen et al. 2018, Berkeland et al. 2019). The amount of mortality observed at monitoring sites indicates that recent adult survival is likely below this 95–97% threshold. In addition, telemetry data from this same population indicate that adult survival is about 89% (Lapin et al. 2019). Based on the results of these analyses, it is possible that this northeast population is declining, as the different analyses indicate either a stable or declining population. Threats to adult Wood Turtles are of major concern for population viability given the high adult survival rate needed to maintain a stable population.

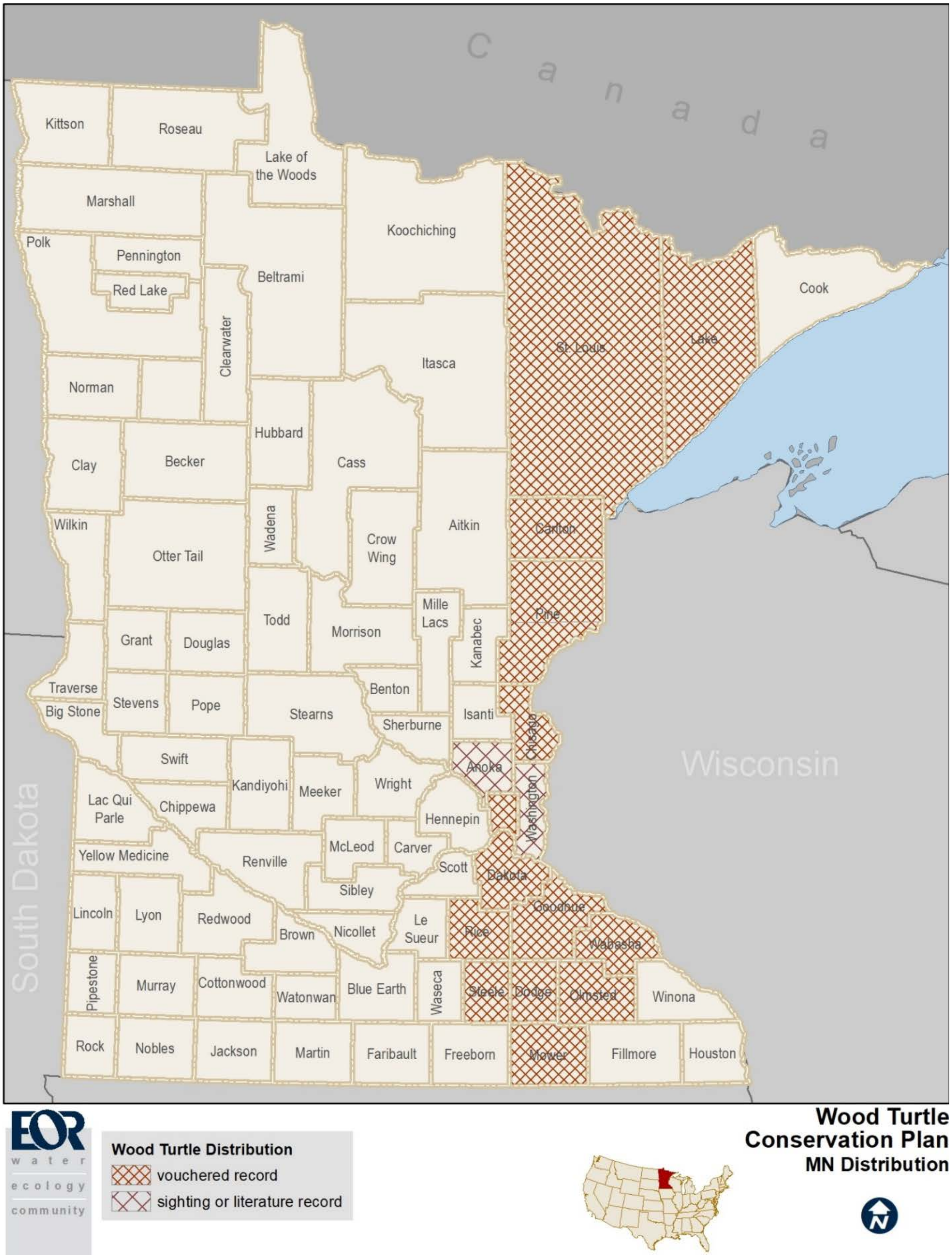


Figure 2. Wood Turtle distribution in Minnesota by county (Moriarty and Hall 2014).

2.5. ECOLOGY AND LIFE HISTORY

2.5.1 Phenology

The active season for Wood Turtles begins in mid to late April when they emerge from hibernation, with turtles in the southeast emerging slightly earlier (Moriarty and Hall 2014, C. Hall, personal communication). Turtles typically remain close to the river early in the year, basking on warm days (Moriarty and Hall 2014, Crozier and Hamady 2018). Wood Turtles breed primarily in the spring and fall (Walde et al. 2003, Moriarty and Hall 2014). Nesting activity typically occurs in late May through June. In two northeast Minnesota populations, the earliest turtles were observed nesting was May 15 and the latest was June 25 (Berkeland et al. 2019, J. Hines and D. Ryan, personal communication). Females may travel long distances to nesting sites. Once nesting is over, more time is spent in uplands away from the river, particularly by females (Moriarty and Hall 2014, Crozier 2020). Hatchlings emerge from nests in mid-August to early October. In a northeast population during 2015–2018 nesting surveys, the earliest that hatchlings were observed emerging from nests was August 10 and the latest was October 10 (Berkeland et al. 2019). The active season lasts through October, when Wood Turtles migrate to aquatic hibernacula (Moriarty and Hall 2014). See **Figure 3** for a summary of Wood Turtle phenology in Minnesota.

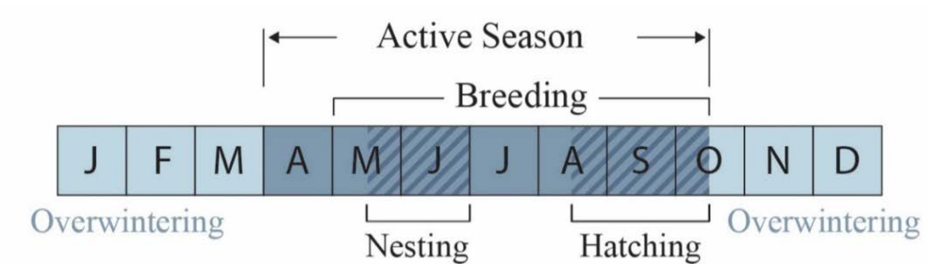


Figure 3. Wood Turtle phenology in Minnesota (Moriarty and Hall 2014, Berkeland et al. 2019; adapted from WDNR 2015).

2.5.2 Habitat

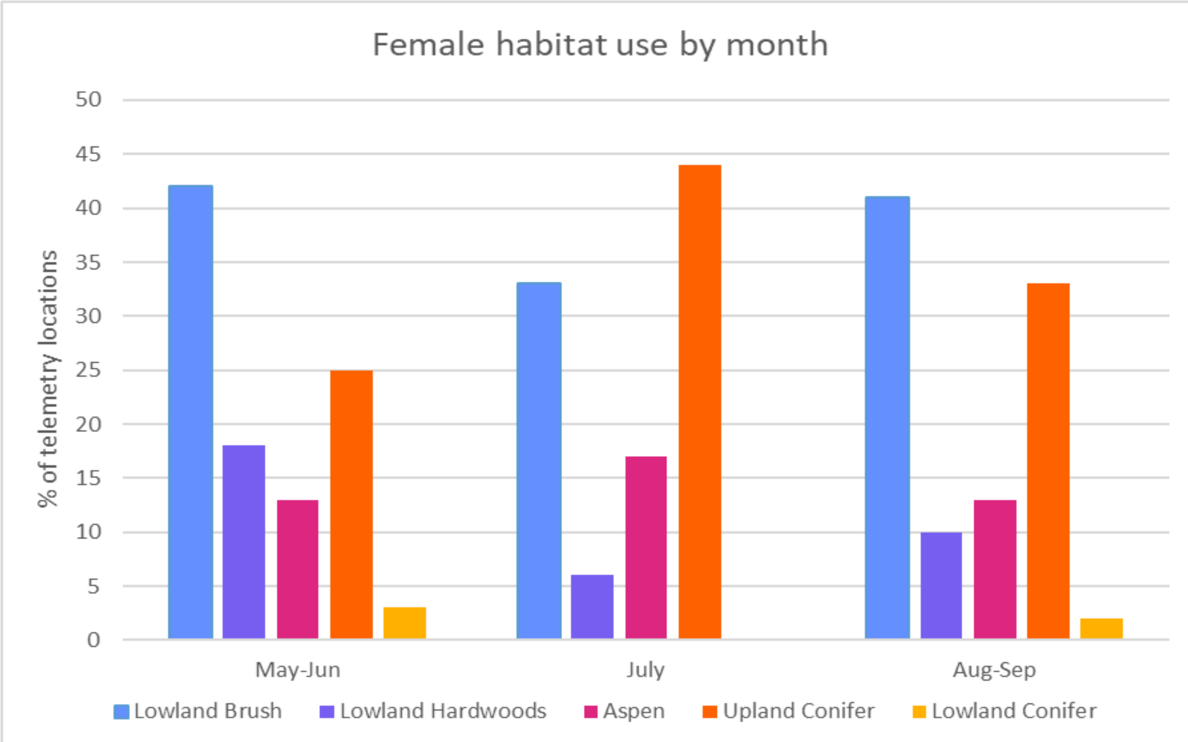
Wood Turtles generally occupy areas in and around small- to medium-size, moderate- to fast-moving rivers and streams (Harding 1997, Ernst and Lovich 2009). Rivers with a narrow floodplain and abrupt transition to uplands characterize the preferred habitat in Minnesota (Moriarty and Hall 2014). Watercourses with sand, gravel, or cobble substrates are preferred (Buech et al. 1997, Ernst and Lovich 2009). In Minnesota, Wood Turtles use a variety of near-water habitats depending on the season and activity, and generally remain within 100 meters of flowing water (Buech 1995, Moriarty and Hall 2014, Brown 2016). However, Wood Turtles in both southeast and northeast Minnesota may travel over 250 meters from water, with northeast females frequently traveling >400 meters in June–August (Berkeland et al. 2019, Crozier 2020, C. Hall, personal communication). Though largely aquatic, Wood Turtles are the most terrestrial of Minnesota turtle species and feed mainly on land (Ewert 1985, Moriarty and Hall 2014). In Maine and Quebec, alder thickets, forest, and grasslands are used for basking and foraging, with preference given to relatively open areas of mixed forest (Compton et al. 2002, Arvisais et al. 2004).

In southeastern Minnesota, Wood Turtles frequently utilize human-altered landscapes. For example, Wood Turtles are frequently found foraging in agricultural fields near rivers (MNDNR 2018) and are known to consume corn kernels that fall to the ground. In southeastern Minnesota, a radio-tagged male was frequently relocated foraging in a large, dense stand of reed canary grass during the summer of 2017, 2018, and 2019. A radio-tagged female was frequently located in a black walnut plantation in 2009 and 2010.

A recent study in a northeast Minnesota population indicated adult Wood Turtles are most frequently found in lowland brush, lowland hardwoods, pine, and aspen from May–September (**Figure 4**; Berkeland et al. 2019, Crozier 2020). Wood Turtles avoided lowland conifers, and there is some evidence they may avoid young aspen relative to its availability. Females were most frequently found in lowland brush such as alder and upland conifer (primarily jack pine, red pine, and white pine). Females used lowland habitats more frequently in May–June (63%), upland habitats more frequently in July (61%), and upland and lowland habitats fairly equally in August–September (about 50% each). Males were most commonly found in upland conifer (primarily jack pine), but they also used aspen, lowland brush, and lowland hardwoods. Males used lowland and upland habitats fairly equally (about 50% each) in May–June, upland habitats more frequently in July (76%), and upland habitats more frequently in August–September (62%).

In this study, adult Wood Turtles were more frequently found in older forest >50 years old, specifically lowland hardwoods, jack pine, red pine, white pine, and aspen (**Figure 5**). However, Wood Turtles also used young and intermediate-aged forest (most notably jack pine 11–25 years old), but at a lower frequency than older forest. Use of young and intermediate-aged forest was highest in July compared to the other months. Observations of upland forested stands with high use during the summer activity period found that stands are typically older with large diameter trees and large canopy gaps containing dense herbaceous vegetation and shrub growth (Crozier 2020). Telemetry data showed that turtles most frequently used the portion of the stands with large canopy gaps interspersed with mature forest, presumably to meet both food and thermoregulatory needs.

Wood Turtles using woody debris and dense shrubs for early season loafing area. J. Naber



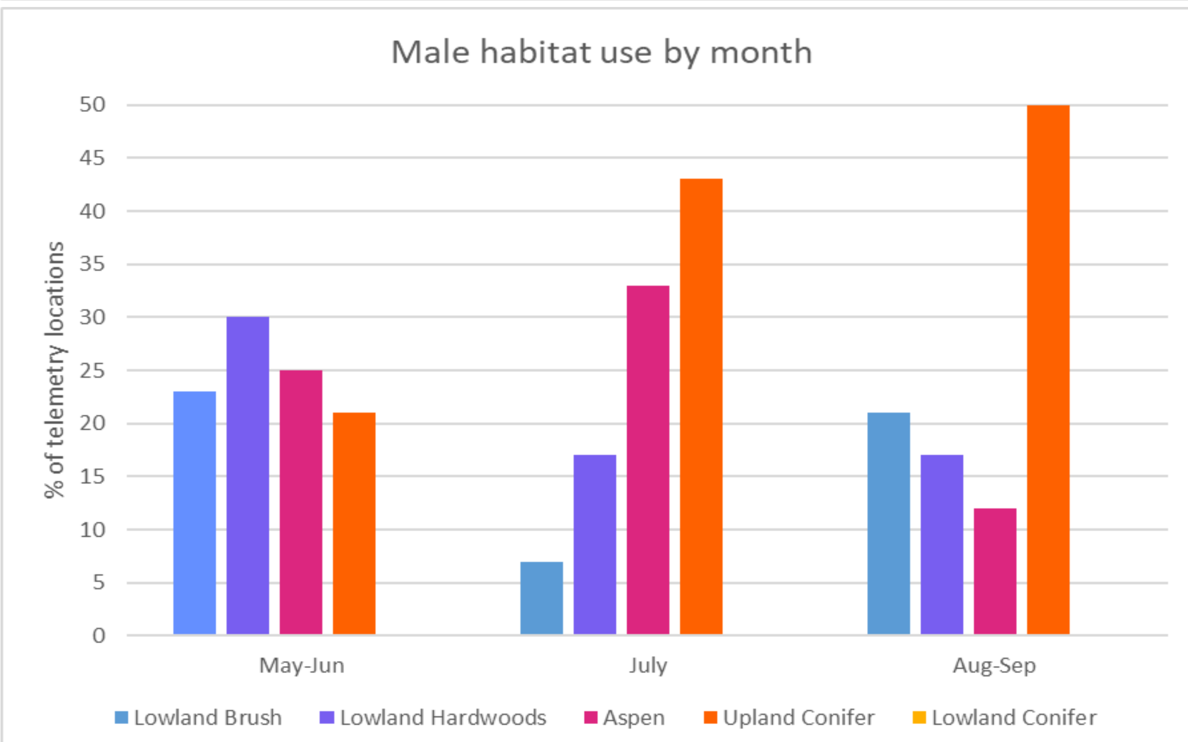
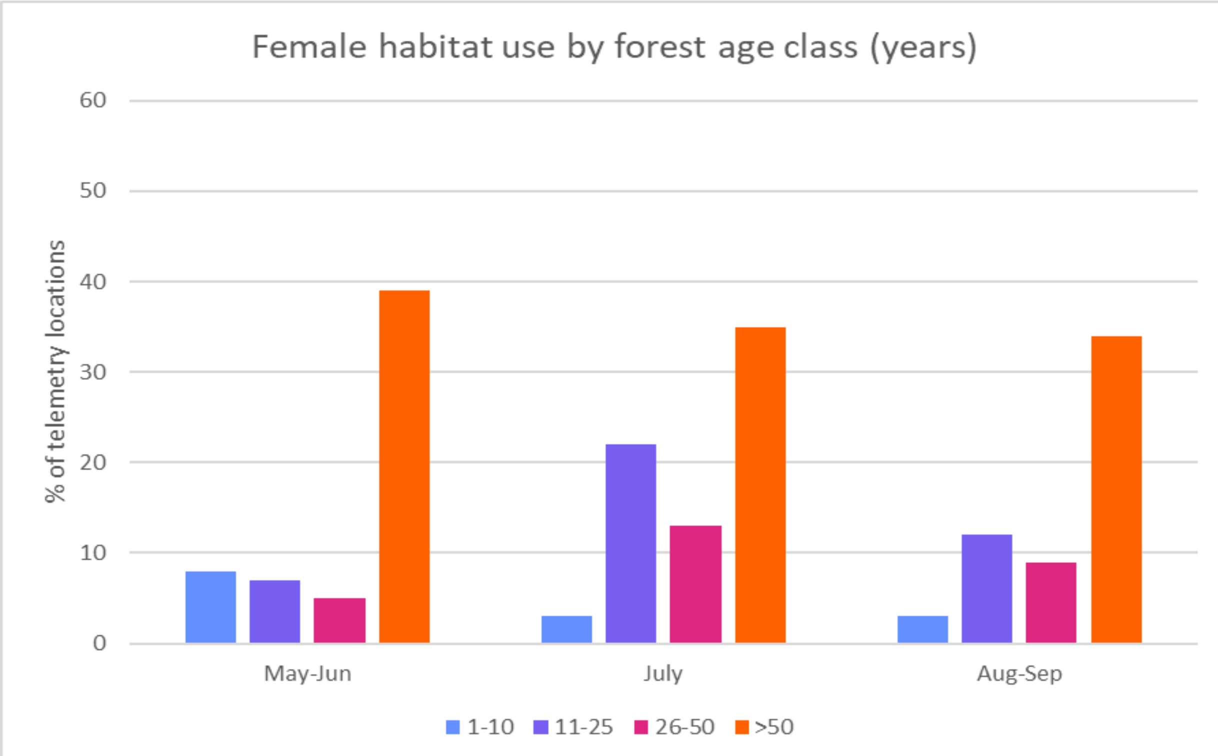


Figure 4. Female and male habitat use by month for one Wood Turtle population in northeast Minnesota (Berkeland et al. 2019, Crozier 2020).



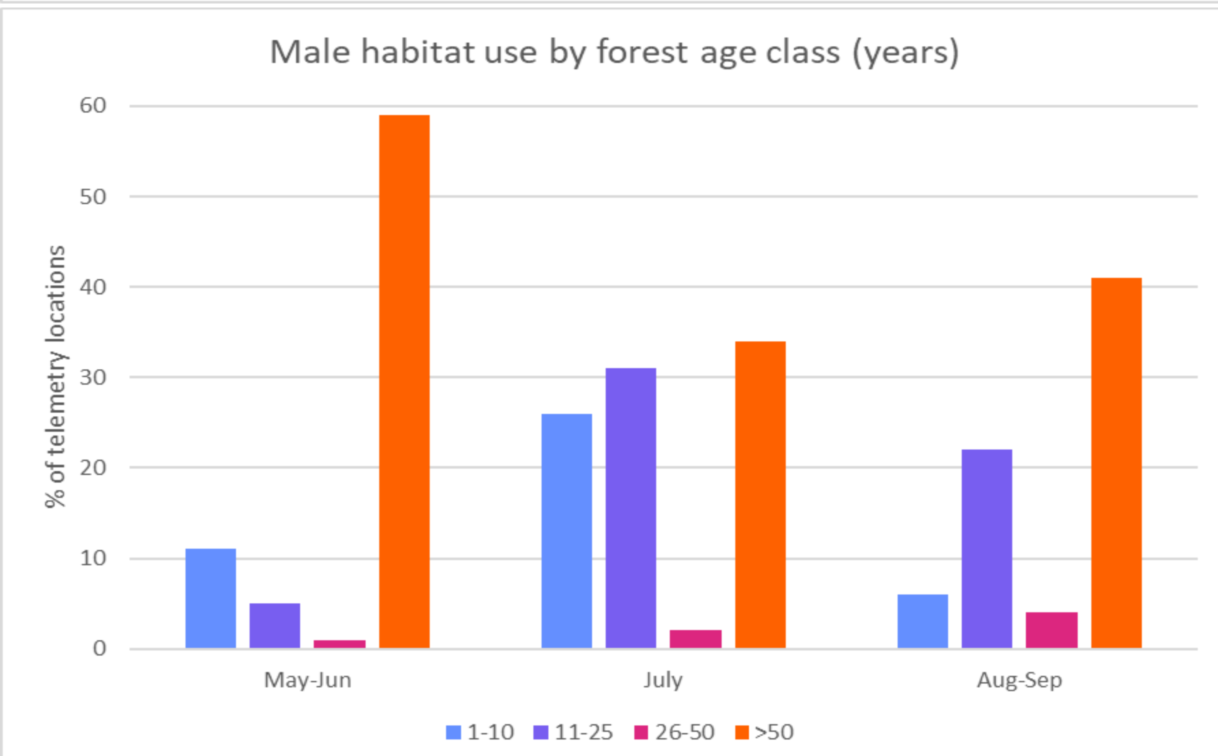


Figure 5. Female and male habitat use by forest age class for one Wood Turtle population in northeast Minnesota (Berkeland et al. 2019, Crozier 2020).

Ideal nesting habitat consists of sandy or gravelly areas with little vegetation, abundant light, and low risk of flooding (Buech et al. 1997, Moriarty and Hall 2014). Many habitats, both natural and modified, may serve as nesting sites and include dry prairie, sand and gravel bars, sandy points, sandy cutbanks, gravel pits, road and utility rights-of-way, and agricultural fields (Harding 1991, Foscarini 1994, Buech et al. 1997, Jones et al. 2015). Buech et al. (1997) identified six key habitat variables at nest sites: soil substrate, slope, aspect, elevation above water, distance to open water, and vegetative cover. In northeastern Minnesota suitable nest sites are generally sand and sandy gravel substrates. Slopes vary from nearly flat to 40°; when slopes exceed 20° southerly aspects are preferred. Most nest sites are located between 2–5 meters above base-flow water levels, and typically within 10 meters of open water. Sites with less than 20% vegetative cover are favored. In one population in northeast Minnesota, nests on average were 18.8 meters from water, 2.5 meters in elevation above the water, and had 6.7% canopy cover (Cochrane et al. 2017a). Nest sites in southeastern Minnesota have not been studied in as much detail, but similar conditions are likely required. Several surveys have focused on potential natural nesting sites in the southeast, with documented sites including sand points, cut banks, old and agricultural fields, and a dormant gravel quarry (Mullins 2000, Holman 2004, Hamady and Hall 2011, C. Hall, personal communication). Prior to laying their eggs, females stage near a preferred nesting site such as a sand point, cut bank, or agricultural field. During the day, they may take cover under alders, willows, grasses, forbs, or row crops adjacent to the nest site (Walde et al. 2007, C. Hall personal communication). However, in some cases females remain in the water near the nesting site, waiting until evening to emerge. Nesting activity typically commences around dusk when test-digs are attempted, and sometimes efforts include multiple nights prior to the selection of a chosen nest site (B. Perry and K. Larson personal communication).

Hatchling and juvenile habitat use is poorly understood relative to adults. After emergence from the nest cavity (typically during daylight hours), hatchlings favor cooler areas with cover of herbaceous vegetation, woody debris, and leaf litter to avoid predation and desiccation (Tuttle and Carroll 2005, Castellano et al. 2008. Paterson et al. 2012). After hatching, open uplands were strongly preferred to wooded uplands for an Ontario population (Paterson et al. 2012). Hatchlings generally move toward aquatic environments typical of adult use, but some studies suggest that prolonged time (up to 24 days) is spent in terrestrial habitat prior to moving to aquatic environments (Tuttle and Carroll 2005, Tamplin 2016).

In 2010, four telemetered hatchlings in northeastern Minnesota spent about 5 weeks foraging in herbaceous vegetation on the nesting site, with the one remaining hatchling moving to the river to hibernate adjacent to the nest site under a large downed tree (G. Crozier, personal communication). Head-started Iowa hatchlings remained within 200 meters of the nest/release site and became almost exclusively aquatic as temperatures cooled (Tamplin 2016). In Minnesota, six turtles less than 1-year old were observed at a nest site in mid-June, suggesting that these turtles may have overwintered near the nest site (Hamady and Hall 2011). Telemetered juveniles in Iowa generally used the same habitats as adults; however, they spent more time in aquatic habitats and less time in grassy and shrubby areas compared to adults (Tamplin 2019).

Wood Turtles hibernate beneath the ice within a watercourse and use a variety of locations depending on oxygen availability. Wood Turtles are considered anoxia intolerant and require oxygenated waters to survive hibernation (Ultsch 2006, Greaves and Litzgus 2008). Hibernacula locations include on the streambed, roughly one meter from the bank, near structures such as bank undercuts or logjams, or within backwater ponds (Moriarty and Hall 2014, C. Hall, personal communication). Hibernacula sites documented in one population in northeastern Minnesota primarily include locations within the main river course in the center of the river or in near-shore environments (Huston et al. 2018). Riverbanks near the hibernacula sites were typically dominated by alder. Water depth at hibernacula locations was 1 meter on average with an ice thickness of 25 centimeters. Mean dissolved oxygen was 9.2 ppm and mean conductivity was 29 µS/cm. Selection of hibernacula sites in northeastern Minnesota for physical, chemical, and thermal properties is unclear; sites did not differ in these conditions compared to random locations within the river. There was also no difference between male and female hibernacula locations.

2.5.3 Diet and Foraging

Wood Turtles are opportunistic omnivores with a diversity of reported food sources. Dominant components of their diet include plant material such as fruits, leaves, and succulent forbs, and invertebrates such as earthworms and insects (Ernst and Lovich 2009, Moriarty and Hall 2014). Fungi, algae, mollusks, eggs, carrion, and small vertebrates like tadpoles and young mice are also consumed by the Wood Turtle (Jones et al. 2015). In southeastern Minnesota, scat collected during transmitter maintenance has revealed crayfish and land snail shell fragments in their diet, as well as kernels of corn. Radio-tagged turtles occasionally have slug fragments on their mandibles when captured.

2.5.4 Reproduction, Survivorship, and Population Structure

Wood Turtles reach sexual maturity between approximately 14–18 years of age; maturation may occur later in more northern latitudes (Moriarty and Hall 2014). Mating commonly transpires in shallow water no deeper than 1.2 meters (Walde et al. 2003, P. Leete, personal communication); however, terrestrial mating also occurs (J. Tamplin, personal communication). Females lay one clutch of 4–18 eggs per year, though clutches typically include 7-9 eggs and may not be laid every year (Ernst and Lovich 2009, Moriarty and Hall 2014). The incubation period reportedly ranges from 58–71 days (Moriarty and Hall 2014), though field data collected in the northeast and southeast regions suggest incubation periods up to 122 days (Cochrane et al. 2017a, C. Hall, personal communication). In the northeast, the average number of hatchlings per nest was 8.5 (Cochrane et al. 2017a).

The Wood Turtle is a long-lived species with a Type III survivorship curve (Akre 2002). Species with Type III curves experience high mortality early in life, with low mortality following the initial bottleneck. Nest depredation by mesopredators is extremely high. A study in one population in northeastern Minnesota found 5% of Wood Turtle nests are successful (Cochrane et al. 2017a). In this study, the most common nest predator was the badger, with smaller numbers of nests depredated by ravens, raccoons, skunks, and foxes (Cochrane et al. 2017a, Berkeland et al. 2019). However, the large number of nests depredated by badgers in this northeast population is likely unique to this part of Minnesota.

Reported survivorship of Wood Turtle hatchlings is extremely low; hatchling survival from nest emergence until winter dormancy was only 11% for a study in Ontario (Paterson et al. 2012), although hatchlings that were lost were assumed to be dead. In contrast, 7 of 8 radio-tracked hatchlings survived until winter dormancy in Iowa (J. Tamplin, personal communication). Survivorship increases for young adult turtles, but a study of Wood Turtles in Massachusetts and New Hampshire reported young adults are twice as likely to experience mortality as old adults (Jones 2009). Adult survivorship exceeded 80% in several studies in Virginia, New Hampshire, and Maine; estimates in Wisconsin have been reported between 73% and 84% and estimates from a long-term study in Michigan have been reported at 97% (Compton 1999, Akre and Ernst 2006, Lapin et al. 2016, WDNR 2016, Schneider et al. 2018). Adult survival estimated from radio-telemetry data in Minnesota was 89% (Lapin et al. 2019). Examining telemetry data across Minnesota, Wisconsin, and Iowa, predation was responsible for 75% of the mortalities when cause of death could be determined (Lapin et al. 2019).

Population modeling and population reconstruction based on almost 30-years of mark-recapture data found that the following survival rates are needed to produce the age-class structure observed in a northeastern population: annual survival of adults (>15 years old) at 95% or higher, annual survival of juveniles (1–15 years of age) at 80% or higher, and survival of eggs through one year of age as 5% or higher (Moen et al. 2017, Berkeland et al. 2019). The oldest Wood Turtle caught in the northeast was a female at least 55 years old (Brown et al. 2015). For turtles to reach 55 years of age, survival analysis shows that annual adult survival needs to be about 97% (Moen et al. 2017, Berkeland et al. 2019).

Population structure of Wood Turtles is variable for both sex ratios and adult to juvenile ratios (Jones et al. 2015, WDNR 2016). Populations are generally composed of a higher or equal ratio of females to males. Wisconsin population sex ratios range from near equal to female-skewed, while Iowa populations show a nearly equal ratio (LeClere 2013, WDNR 2016). Likewise, adult to juvenile ratios are typically higher. However, many studies are skewed due to search biases toward nesting females during surveys and low detectability of juveniles.

Population structure was studied for a northeastern Minnesota population based on 2016–2018 monitoring at eight sites each approximately 500 meters in length (Berkeland et al. 2019). Estimated abundance varied greatly among sites and years and ranged from 1–77 individuals per site. For all sites combined, adult sex ratio varied annually from 1.3 females to 1.7 females per male, and juvenile-adult ratio was about 0.2 juveniles per adult annually (Crozier 2020). From the population reconstruction of the same population based on almost 30 years of mark-recapture data (Berkeland et al. 2019), sex ratio was 2.7 females to 1 male. The estimated juvenile-adult ratio is likely somewhere between 0.5 to 0.75 juveniles to 1 adult. Both sex and juvenile-adult ratios are skewed due to many of the surveys taking place at nesting sites during the staging and nesting season which biases the results to adult females.

2.5.5. Movements and Home Range

Wood Turtles generally remain within 300 meters of flowing water (Ernst 2001, Arvisais et al. 2002, Compton et al. 2002, Tuttle and Carroll 2003, Remsberg et al. 2006); telemetry studies in Minnesota suggest individuals typically stay within 100 meters of flowing water (Buech 1995, Brown 2016). Wood Turtles remain closer to water early in the season and travel farther during summer based on temperature, foraging requirements, breeding, and the search for nest sites by females (Ernst 1986, Moriarty and Hall 2014). The most extensive movements are along watercourses and usually related to males searching for a mate or females searching for a nest site (WDNR 2016). In southeastern Minnesota, males appear to spend more time in the water than females (T. Markle, personal communication). Daily movements are highly variable and depend on resource availability, seasonality, and geography. Terrestrial maximum daily movements are reported between 410-900 meters and aquatic maximum daily movements are reported up to 2,940 meters (Tuttle 1996, Ernst 2001, Walde et al. 2007).

Telemetry data from one population in northeastern Minnesota showed that adult Wood Turtles moved an average of 0.58 meters/minute (Berkeland et al. 2019, Crozier 2020). Male turtles on average stayed closer to the main river channel than females. Males consistently stayed within about 200 meters of the river throughout the active period. Females traveled farther from the river than males in all months. Some female turtles had a similar pattern to male turtles and stayed close to the river (<200 meters) throughout the active period. However, some females traveled far from the river, particularly in June–August. About 23% of female turtles traveled >400 meters from the river in June-August. The maximum distance a female turtle traveled from the river was 524 meters.

Observations from this telemetry study suggest males and females exhibit different movement patterns (Crozier 2020). Males typically stay in a single activity area near the river, sometimes traveling 0.8–1.6 kilometers along the river. Females may also have a single activity area near the river, but typically venture farther into the uplands from the river than males. Additionally, females may have two distinct activity areas: a nesting activity area near their nesting site and a summer activity area near their hibernacula site.

Recently hatched Wood Turtle with small telemetry tracking device attached. MN DNR

Wood Turtle telemetry tracking. C. Hall.

The general pattern for these turtles with two activity areas is that they emerge from hibernation and spend early spring near their hibernacula site. They then travel using the river and river corridor to their nesting location and spend the staging and nesting period in this location. During the post-nesting period, they travel back to their hibernacula area and spend the rest of the summer in the general area of the hibernacula site. While these turtles stay in the general area of their hibernacula site until hibernation, they venture farther from the river in July and August before staying closer to the river by early fall. The distance between the nesting activity area and the summer activity area near the hibernacula site ranged from 1.6–8.7 kilometers. Turtles telemetered for multiple years showed strong site fidelity to their nesting and summer activity areas.

Home ranges of Wood Turtles vary based on geography, sex, habitat quality, drought, distance to hibernaculum and nesting sites, and estimate method (Arvisais et al. 2002, Remsburg et al. 2006, Environment Canada 2016). Like Wood Turtle movements, home ranges generally are constricted along watercourses and have an elongated shape (Environment Canada 2016). Telemetry data from one population in northeastern Minnesota from 2015–2016 was used to assess home range, which was found to be highly variable between individuals (Drescher-Lehman 2019). For females, average home range size was 220 hectares with a range of 3–1245 hectares. For males, average home range size was 59 hectares with a range of 3–255 hectares. Females generally had larger home ranges because of traveling to nesting sites (Drescher-Lehman 2019). Several studies in Wisconsin measured home ranges between 0.1–278.3 hectares using different estimation methods, with average home ranges from 7.4–20.5 hectares depending on sex and region (WDNR 2016).

3. PAST AND CURRENT CONSERVATION EFFORTS IN MINNESOTA

There has been considerable effort to understand the distribution, abundance, and life history of the Wood Turtle in Minnesota and to manage and protect Wood Turtle populations. Surveys, monitoring, research, management, and protection efforts have occurred over the past four decades, often as a collaborative effort among agencies, universities, non-profits, and contractors. However, many Wood Turtle studies have been short-term and conducted on one population or a discrete area within one population. Long-term studies in multiple watersheds are needed to fully understand the dynamic nature of Wood Turtle habitat and populations.

In 2008, the MNDNR's Nongame Wildlife Program initiated a series of meetings to begin the development of a recovery plan for Wood Turtles in Minnesota. It was determined that there was not enough information to proceed with a recovery plan at that time. Critical knowledge gaps were identified, and the State Wildlife Grant (SWG) and competitive State Wildlife Grant (cSWG) projects from 2009-2019 described in this Chapter were undertaken by the MNDNR to help fill some of these critical knowledge gaps. All the efforts described in this Chapter created the foundation for this Conservation Plan. Future research and management projects will build off these efforts to continue our understanding of Wood Turtles.

3.1 SURVEYS AND MONITORING

The Minnesota Natural Heritage Information System (NHIS) includes historic records of Wood Turtle occurrence from the 1930s to present. The NHIS provides baseline data on the Wood Turtle's range within Minnesota and includes records collected during targeted surveys conducted by professionals and incidental citizen sightings reported to MNDNR. The first formalized surveys for Wood Turtles consisted of reconnaissance type surveys initiated in the 1980s to document distribution and abundance in both northeastern and southeastern Minnesota (Ewert 1984). These reconnaissance surveys suggested the most significant Wood Turtle populations were in northeastern Minnesota. During the 1990's and 2000's, the Minnesota Biological Survey (MBS) coordinated surveys throughout much of the Wood Turtle's range in Minnesota with the goal of adding new and updated records to the NHIS database. Numerous surveys have since been conducted and are described in approximate chronological order and by region below.

Surveys of the Northeast L and Northeast D rivers in northeastern Minnesota were conducted by the U.S. Forest Service (USFS) in the early 1990s, nesting sites were identified, and telemetry was used to examine movement patterns and habitat use (citation redacted; Buech 1995). Additional informal surveys of the Northeast L and Northeast D rivers continued from the 1990s to the present by USFS, MNDNR, and Fond du Lac Band of Lake Superior Chippewa. Surveys of the Northeast K River began in 2000 and continue into the present (Naber 2001, J. Naber, personal communication). In central Minnesota, general turtle surveys documented Wood Turtle occurrence in the Northeast B River (citation redacted). MNDNR also conducted surveys on several tributaries of the Northeast M River in 2000 and 2001. In southeastern Minnesota, surveys were conducted by the MNDNR and Place D during the 1990s on the Southeast B, Southeast D, Southeast A, and Southeast C rivers and suggested low populations in the region (Erpelding 1998, Hines 1999, Mullins 2000). The surveys conducted throughout the state since the 1990s support that the most robust populations remain in the northeast while many southeastern populations appear small and imperiled.

Surveys were conducted along the Southeast D River in southeastern Minnesota in 2002 and 2003 (Holman 2004). The Northeast G and Northeast F rivers were surveyed in 2007 but did not record any individuals (Hines 2007). In 2009 and 2010, a State Wildlife Grant (SWG) provided funding for MNDNR to survey under-surveyed river sections distributed throughout the Wood Turtle range in Minnesota (Hamady and Hall 2011). These rivers included the Northeast I, Northeast C, Northeast D, and Northeast K rivers in the northeast, the Northeast A River in the central, and the Southeast C and Southeast A rivers in the southeast (Naber and Majeski 2009, Naber and Majeski 2010, Hamady and Hall 2011). Smaller tributaries in the northeast were also surveyed and included the Northeast H River, Northeast J Creek, and Northeast E Creek (Naber and Majeski 2009, Naber and Majeski 2010). These surveys covered a wide range of conditions in different rivers allowing for comparison of different systems within the major areas of Wood Turtle concentration in the state.

Identifying Wood Turtles with comparing shell patterns with photo records. C. Hall

From 2013–2019, two competitive State Wildlife Grants (cSWG) were awarded to the states of Minnesota, Wisconsin, Michigan, and Iowa to take a regional approach in examining threats and effectiveness of conservation efforts for Wood Turtles (Crozier 2018; Crozier and Hamady 2018, Crozier 2020, Hoekstra and Lapin. 2020). In Minnesota, the MNDNR and University of Minnesota implemented conservation actions on the Northeast L River such as creating nesting sites, restoring foraging habitat, protecting nests from depredation, and installing road barriers. Effectiveness was assessed using surveys, remote cameras, and telemetry (Crozier and Hamady 2018, Berkeland et al. 2019, Crozier 2020). A long-term monitoring protocol was developed to assess long-term effectiveness of the conservation actions (Brown et al. 2017), and baseline monitoring data were collected on the Northeast D and Northeast L rivers (Berkeland et al. 2019). The same protocol was used to collect baseline monitoring data in Wisconsin (Hoekstra and Lapin. 2020), which will allow for regional assessments in the future.

Additional recent efforts include surveys in southeastern Minnesota led by MNDNR and the Minnesota Zoo (MN Zoo) funded in part by a SWG grant and Legislative-Citizen Commission on Minnesota Resources (LCCMR) funds (Naber and Majeski 2017, T. Markle, personal communication). These most recent Wood Turtle surveys confirm that most significant populations in Minnesota remain in northeastern Minnesota. However, a complete understanding of the range, distribution, and abundance of the Wood Turtle population remains elusive due to low densities and difficulty of observation in many river reaches of the state.

3.2 RESEARCH

Wood Turtle research in Minnesota has included the study of population trends, habitat use and movement, habitat restoration, nesting, hydrology, and road mortality. Research completed to date is foundational to the Conservation Plan and will be a critical component of future conservation and recovery efforts.

3.2.1 Population Trends and Modeling

Only recently have attempts been made to determine population trends of the Wood Turtle in Minnesota (Cochrane et al. 2018, Berkeland et al. 2019). The population trends for the Northeast L River described in Section 2.4.3 were investigated as part of the 2013–2019 cSWG project. An integral part of this research consisted of development of a long-term monitoring protocol (Brown et al. 2017). Long-term monitoring sites were established, and baseline data were collected on the Northeast L and Northeast D rivers with the intent to monitor these sites every five years (Berkeland et al. 2019). Ten population and habitat parameters were developed to best evaluate long-term response of Wood Turtle populations, specifically regarding conservation actions (Crozier and Hamady 2018). Population modeling was conducted on the Northeast L River as part of the cSWG project and consisted of a population reconstruction to examine population trends and population structure (Moen et al. 2018, Berkeland et al. 2019). Modeling is being used to evaluate the influence of adult survival and juvenile recruitment on population stability so that management actions can be focused on the most critical aspect of population viability.

3.2.2 Habitat Use and Movement

Downloading data from GPS logger on radio-tagged Wood Turtle . C. Hall

Telemetry surveys have been used to characterize Wood Turtle habitat use and movement in Minnesota since the 1990s. Most recently, telemetry was implemented in both the northeast and southeast regions by the MNDNR, University of Minnesota, and MN Zoo. The MNDNR commenced a GPS telemetry pilot endeavor in 2009 and 2010 on the Southeast C and Southeast A rivers (Hamady and Hall 2011). The study laid groundwork for future telemetry efforts and provided insight into habitat use for nesting, foraging, and hibernacula (including location of nest sites on agricultural land). Additionally, informal efforts to track hatchlings using telemetry occurred on the Northeast D River in 2010 (G. Crozier, personal communication).

Telemetry data collected in the 1990s on the Northeast L River were recently analyzed to examine habitat use (Brown et al. 2016). Telemetry was used on the Northeast L River in

2015–2017 as part of the cSWG project to assess Wood Turtle movement patterns, habitat use, and use of conservation action areas (Cochrane, et al. 2017b, Berkeland et al. 2019, Crozier 2020). Assessment of movements and seasonal habitat use provided data on distance traveled from the river, types of habitat used, locating and characterizing hibernacula, and how these parameters vary by sex and season. These data were also used to evaluate home range and movement speed (Drescher-Lehman 2019). These results are integrated into Section 2.5 of this report.

Beginning in 2017, telemetry in the southeast focused on a small number of sites along the Southeast D and Southeast B rivers, expanding in 2018 and 2019 to additional sites and the Southeast A River (T. Markle, personal communication). In 2018, the MN Zoo also released five head-started turtles fitted with radio transmitters. Tracking of these turtles will continue into 2020. This research is possible through a partnership between the MNDNR and MN Zoo, and funded by a 3-year LCCMR grant. This research will provide data on habitat use and movements in the southeastern Wood Turtle populations with an overarching aim to characterize the threats of road mortality and nest predation on several turtle species, including Wood Turtles. The research will also investigate mechanisms to improve imperiled species conservation, such as improving hatching success.

3.2.3 Habitat Restoration

In 1990, the USFS created a nesting site on the Northeast L River to provide an alternate for Wood Turtles utilizing a nearby gravel road for nesting. The cSWG project from 2013–2019 facilitated MNDNR to restore this nest site, create 21 additional nest sites, and restore seven foraging areas consisting of jack pine stands on the Northeast L River (Crozier and Hamady 2018, Crozier 2020). Research included monitoring of Wood Turtle use following habitat restoration or creation. Wood Turtles used the restored nesting site during the study, but there was no evidence that turtles used the created nesting sites (Crozier and Hamady 2018, Berkeland et al. 2019, Crozier 2020).

3.2.4 Nest Success and Depredation

To address nest depredation, cSWG funding from 2013–2019 allowed monitoring of 156 Wood Turtle nests along the Northeast L River, including 29 nests equipped with nest cages and a minimum of 10 nests protected with an electric fence (Berkeland et al. 2019). The study monitored nest success of protected and unprotected nests, documented depredation, and collected ancillary biological and environmental data at each nest. Motion sensor cameras deployed at 36 nesting or potential nesting sites captured predator observations and depredation events, providing species-specific identification of predators and behavior. When feasible, hatchlings were PIT-tagged (passive integrated transponder) following emergence from nests. Caged nests increased nest success to 48% but installation and monitoring proved challenging and time intensive. Badgers were the most frequently documented nest predator and learned to dig up cages during the second year of study. The electric fence was a more efficient and effective way to reduce nest depredation.

Wood Turtle eggs collected for head start program. C. Hall

The MN Zoo is currently working with MNDNR to identify potential nesting areas for Wood Turtles in southeastern Minnesota to meet the objective of improving hatching success and to protect those areas from mammalian predators using electrified fences (T. Markle, personal communication). Two nest protection fences were installed in spring 2019 along the Southeast D River, and additional nesting areas will be protected in 2020. In 2019, the MN Zoo also reared eggs from three at-risk nests to evaluate head-starting as a technique to increase survival; additional investigation of head-starting will continue in 2020.

Recent research has also considered the impacts of altered hydrology on Wood Turtles due to land use and climate change. Lenhart et al. (2013) examined the long-term change in suitability of flows for Wood Turtle nesting in both northeastern and southeastern Minnesota. This study concluded that hatching is likely delayed in agricultural watersheds due to prolonged inundation of sandbar nest sites compared to pre-1980s conditions. Hydrologic modeling as part of the 2013–2019 cSWG determined flood risk of nesting sites and identified flood-safe sites suitable for conservation or restoration action (Naber and Ulrich 2016, Crozier and Hamady 2018). Nest site flooding was minimal on the Northeast L River during the study; however, flooding may be more of an issue on the Northeast D River (Crozier 2020).

High water covering sandy banks of the Northeast D River, MN. J. Naber

3.2.5 Road Mortality

Identification and management of high-risk locations for Wood Turtle travel was investigated using telemetry during the 2013–2019 cSWG (Crozier and Hamady 2018, Berkeland et al. 2019). Telemetry identified roads that have the greatest potential for mortality. High-risk locations were typically associated with turtles nesting on road shoulders and areas where turtles crossed roads to forage during July and August. Turtles did not typically cross roads during travel to nest sites located near the river, instead using the river as the primary travel corridor. Observations of road mortality on the Northeast D and Northeast L rivers were minimal during the study. However, concerning levels of road mortality have been observed in the past and more work is needed to determine if problems continue to persist.

The efficacy of road barriers to dissuade turtles from crossing and nesting along roads was also evaluated (Crozier and Hamady 2018, Berkeland et al. 2019, Crozier 2020). Temporary road barriers were installed at several high-risk locations. Results indicated that the temporary barriers were not effective at preventing road access and road nesting by Wood Turtles. Turtles traveled around barriers and were able to get through barriers in places where fencing was ripped or torn down by people. More experimentation is needed with barrier material, barrier design, and ways to deal with private lands.

Though not specific to Wood Turtles, the MN Zoo is also actively investigating road mortality of turtles and mitigation strategies to reduce impacts on turtle populations. In collaboration with the Minnesota Department of Transportation (MNDOT), the MN Zoo is evaluating the effectiveness of turtle fences and turtle crossing warning signs. If found to be effective, strategies could be applied in areas where there is potential for Wood Turtles on roads.

Wood Turtle apparently injured by a car strike. J. Naber

3.3 MANAGEMENT AND PROTECTION

Management and protection strategies have generally focused on legal protection, forest management recommendations, environmental review recommendations, and habitat protection. Management partners include the MNDNR, USFS, county forest management, MNDOT, county Department of Transportation, and private citizen efforts. Wood Turtles are legally protected under state law, which prohibits the killing, destroying, and possessing of Wood Turtles without a permit. Management efforts have primarily focused on providing technical guidance on proposed projects to prevent the take of turtles, and if possible, to maintain or enhance habitat. Recommendations generally include seasonal timing restrictions during the active season, protecting nesting areas, creating safe passage under roads, minimizing mowing until late summer, avoiding use of riprap and retaining walls, using wildlife-friendly erosion control blankets, protecting water quality, reducing stormwater runoff, managing invasive species, and limiting recreation in critical areas (MNDNR 2011). The MNDNR has developed forest management guidelines for Wood Turtles to avoid impacting Wood Turtles and their habitat. MNDNR has also developed a fact sheet for environmental review purposes to reduce impacts of projects on Wood Turtles and their habitats. As a USFS Regional Forester Sensitive Species, the USFS has direction to maintain, protect, or improve habitat for Wood Turtles. Guidance includes maintaining or restoring all known breeding locations and protecting nesting areas from predators and negative impacts of recreation (USFS 2004).

Protective habitat fencing for nesting site. C. Hall

A limited number of management projects have occurred specifically to benefit Wood Turtles, including habitat restoration and creation, nest protection, and roadside management. The USFS developed guidelines for creation of nesting areas in 1991 and nest scrapes were created by the USFS in northeastern Minnesota in the 1990s (Buech and Nelson 1991). With cSWG funding during 2013–2019, several management actions were implemented (Crozier and Hamady 2018, Crozier 2020). Restoration activity was conducted on 91 acres of pine forest habitat along the Northeast L River to improve foraging habitat. Nesting habitat was also created or restored in flood-safe areas of the Northeast L River. Nest cages and an electric fence were installed (Section 3.2.4) and road barriers were fitted along high-risk road locations (Section 3.2.5) along the Northeast L River. The efficacy of the actions continues to be assessed and will inform future specific management actions.

Place B was established in 1996 to protect a stretch of river that includes habitat for nesting turtles, including Wood Turtles. Sandbars within the area are closed sanctuaries from May to October 15. In the northeast, efforts are currently underway to establish protections for Wood Turtle habitat on the Northeast D River, and to create management agreements for lands on the Northeast D and Northeast L rivers where habitat protection is not possible.

4. ISSUES, GOALS, AND STRATEGIES

This section identifies the issues, goals, and strategies for the Conservation Plan. The overarching conservation goal for the Wood Turtle in Minnesota was established by the Wood Turtle Planning Team during the development of the Conservation Plan.

Conservation Goal:
To maintain and enhance Wood Turtle populations throughout their range in Minnesota with the goal of having viable populations.

The Wood Turtle Planning Team subsequently identified issues affecting the Conservation Goal and established broad, statewide 10-year goals that address each issue. Strategies and sub-strategies were identified to progress toward the 10-year goals. The strategies identified in the Conservation Plan will start moving the species toward recovery and can be used to inform a future recovery plan.

1. **Issue Statement:**
   An issue is defined as a factor or stressor affecting the Conservation Goal. In most cases, an issue has multiple sub-issues which affect it. The issues identified and prioritized in this plan were used to define the goals, strategies, and implementation activities. Five issues were identified and are discussed in this section:
   - Habitat
   - Adult Mortality, Removal, and Sub-lethal Impacts
   - Juvenile Recruitment
   - Knowledge Gaps
   - Partnerships
2. **Desired Future Condition (Long-term Goals):**
   This is a statement describing the desired long-term, future condition of the issue, regardless of timeframe.
3. **10-Year Goal:**
   This is the broad, state-wide objective over the next 10 years after implementing the Conservation Plan.
4. **Strategies:**
   These are the broad conservation strategies to meet the state-wide 10-year goals.
5. **Sub-Strategies:**
   These include prioritized and specific conservation strategies within the strategies.

4.1 HABITAT

4.1.1 Issue Statement

Habitat loss, degradation, and fragmentation pose a serious threat to Wood Turtle populations. Impacts to habitat affect Wood Turtles at all life history stages and are deeply intertwined with the other issues identified within this plan. Potential threats to Wood Turtle habitat include agricultural practices, altered hydrology, forestry practices, invasive plant species, mineral extraction, recreation, and road networks and urbanization. It is important to analyze the impacts of these threats on Wood Turtle populations and consider the cumulative effects of all identified threats to Wood Turtle habitat. Impacts of specific threats vary in scale depending on location, but when combined across the landscape may have a significant effect on Wood Turtle populations. Additionally, climate change is an overarching issue that is linked closely with many of the identified threats and will affect Wood Turtle habitat from regional to site-specific scales and is incorporated where applicable below.

4.1.1-A: Agricultural Practice

Agriculture is a common land use within the Wood Turtle range in Minnesota, especially in the southeast region. Historical and current conversion of land to agriculture is responsible for direct loss and degradation of terrestrial habitat (Jones et al. 2015). Row cropping negatively impacts foraging habitat via reduced plant and invertebrate availability (Saumure and Bider 1998). Indirect effects of agriculture on habitat include sedimentation and pollution of aquatic habitat (Environment Canada 2016). Beneficial foraging habitat may be provided by hayfields, and nesting was documented in agricultural and old fields in southeastern Minnesota (Saumure et al. 2007, Hamady and Hall 2011). Grazing is suspected to have historically maintained open habitat within woodlands of the southeast region, enhancing foraging and potentially nesting habitat (C. Hall, personal communication). However, agricultural habitat use may increase risk of mortality and function as an ecological trap (Section 4.2.1-D; Saumure et al. 2007, Environment Canada 2016, Pappas et al. 2017).

Tracking Wood Turtles in a corn field. C. Hall

4.1.1-B: Altered Hydrology

Wood Turtles rely on natural processes of riparian ecosystems to create and maintain habitat and are sensitive to changes in river hydrology. Flooding frequency, intensity, and duration are increasing, in addition to changes in timing of flows (Lenhart et al. 2013, Jones at al. 2015, Naber and Ulrich 2016, Crozier and Hamady 2018). These changes in hydrology affect Wood Turtle recruitment, including nest flooding, delayed nesting, changes in the creation and maintenance of nest habitat, and loss and degradation of nest habitat. Severe flood events also displace or even drown adult Wood Turtles (Jones and Sievert 2009, Jones et al. 2015).

Anthropogenic alterations such as land use, streambank stabilization, dams, and impoundments are primary drivers of change to hydrologic regimes. Clearing of natural lands, altering vegetation on natural lands, and drainage of wetlands increases runoff, especially when replaced with impervious surface (Jones et al. 2015). Increases in runoff change the timing and amount of water flow as well as sedimentation dynamics. These factors impact nest flooding and availability of nesting habitat. Dams likely caused direct loss of habitat in the past, and they continue to alter riparian systems by withholding substrate that contributes to suitable nest sites and influences flow patterns (Jones et al. 2015). Bank stabilizations featuring riprap or concrete are poor habitat and, like dams, inhibit development of suitable nest sites (Buech 1992, Jones et al. 2015). Some bank stabilizations contribute to increased severity of floods (Jones and Sievert 2009). Climate change compounds hydrologic changes and their effect on Wood Turtles in Minnesota via increased storm frequency, flood events, and more severe drought (Larson and Anderson 2016).

4.1.1-C: Forestry Practices

Forest management is a common land use within the Wood Turtle range in Minnesota, particularly in the northeast region. Forestry practices including road development, forest harvest, forest type conversion, and herbicide use may reduce, degrade, and fragment habitat. Historically, riparian habitat may have been lost or degraded by logging drives as high volumes of trees were floated downriver (COSEWIC 2007). Large tracts of historical pine forest in northeastern Minnesota are now dominated by younger aspen stands. Fire was once the dominant disturbance factor in pine forests and is now largely suppressed (Heinselman 1973, Frelich and Reich 1995), having been replaced by timber harvest. It is unknown what impacts these historic changes may have had on Wood Turtles. Fires result in a flush of herbaceous vegetation and potentially create open areas for nesting and foraging. Pine stands have a different herbaceous ground layer and forest structure compared to more uniform aspen stands. These changes may have impacted the availability of food resources and the quality of habitat conditions for Wood Turtles.

The effects of current forestry practices on habitat have generally not been quantified. Wood Turtles are considered an edge species, moving between open and shady areas to thermoregulate while foraging. Clear-cutting may reduce sources of food and shelter, and areas logged within 10 years generally had low use by adult Wood Turtles (Environment Canada 2016, Berkeland et al. 2019). Forest harvest typically simplifies species and structural diversity of a stand, potentially changing food availability and microhabitat conditions for thermoregulation. Much of the remaining pine forest in the northeastern

Minnesota Wood Turtle range is now managed as pine plantations often using herbicide, likely resulting in low quality habitat. Large amounts of clear-cutting in a watershed may alter watershed hydrology (see 4.1.1-B), potentially increasing sedimentation and nest flooding (COSEWIC 2007). Logging roads fragment habitat, attract turtles to roadside nests creating ecological sinks, and increase recreation along the river, which can degrade nesting habitat (see 4.1.1-F).

Some forestry practices may enhance habitat with proper timing and management of hydrology and soils (Kaufmann 1992; Wesley 2006; Tingley and Herman 2008). Forestry practices that maintain quality native plant communities with high species and structural diversity as appropriate for the plant community can help increase quality habitat. Retaining downed trees and snags (i.e., future downed trees) for thermoregulation and cover can also help enhance habitat.

4.1.1-D: Invasive Species

Invasive terrestrial plant species threaten Wood Turtle habitat, with the most direct observations of impacts at nest sites. Natural nesting sites such as sand points and bars are observed overgrown with reed canary grass (*Phalaris arundinacea*) in Minnesota (Hamady and Hall 2011, Jones et al. 2015). Vegetation management was also an issue for created nesting sites in northeastern Minnesota (Crozier and Hamady 2018). The non-native subspecies of the grass *Phragmites australis* is expanding in Minnesota and could threaten nesting habitat. Invasive species such as reed canary grass and buckthorn (*Rhamnus spp.*) may affect quality or connectivity of foraging and other habitat, but impacts have not been studied. MNDNR has observed foraging activity in patches of reed canary grass, and it is unknown if there are any positive benefits conferred by these communities (C. Hall, personal communication). In addition, non-native, invasive earthworms profoundly impact forest communities (Frelich et al. 2006) and potentially alter food resources for Wood Turtles, though earthworms can serve as a food source (Kaufmann 1986).

4.1.1-E: Mineral Extraction

Mineral extraction, while not a dominant land use in Minnesota, poses potential threats to Wood Turtle habitat. Sand and gravel pits from aggregate mining attract Wood Turtles due to their suitability as nest sites in the absence of natural nest sites. Sand and gravel pits are commonly observed in use by Wood Turtles for nesting (Buech et al. 1997). One study in northeastern Minnesota found that sand and gravel pits were more frequently used by Wood Turtles than would otherwise be expected at random (Brown et al. 2016). These areas can enhance recruitment but may function as ecological traps due to increased exposure to predators, roads, and human disturbance (Crozier and Hamady 2018). One advantage sand and gravel pits have over near-river nesting sites is that they tend to be less flood prone. Research is needed to understand the positive and negative impacts of sand and gravel mines on Wood Turtles.

Metals mining is also a potential issue for Wood Turtle populations in northeastern Minnesota. Iron/taconite mining is a historical and active land use within several watersheds of northeastern Minnesota. Copper-nickel mines are proposed for the region and exploration for copper, nickel, gold, and platinum group metals is ongoing. Potential impacts of metals extraction include altered river flow patterns, increased river sedimentation, surface and groundwater contamination, and direct habitat loss (MEQB 1979). For example, water releases from mining projects may cause flooding of downstream nest sites (Crozier and Hamady 2018).

4.1.1-F: Recreation

Wood Turtle habitat is often attractive for recreation, which can result in negative effects on Wood Turtle populations. Two populations in Connecticut declined due to incidental collection by recreationalists after opening of habitat to fishing and hiking (Garber and Burger 1995). Off-road vehicle and hiking trails may fragment habitat, attract turtles to nest in poor quality habitat, increase risk of illegal collection by recreationalists, and introduce stressors. Off-road vehicles potentially destroy nesting habitat, or even result in mortality from crushing (Environment Canada 2016). Important nesting habitat like sand bars and points are popular stopping points for river recreationists and are easily disturbed or destroyed. Furthermore, trash left near nesting habitat attracts predators and increases risk of nest depredation (Strickland and Janzen 2010).

ATV damage on near-river nest site. J. Naber

4.1.1-G: Road Networks and Urbanization

Urbanization affects Wood Turtle habitat both directly and indirectly. Most obviously, conversion of land cover to urban use causes direct habitat loss, degradation, and fragmentation (Elmqvist et al. 2016). Indirect impacts include altered riparian hydrology, poor water quality, and reduced biotic richness due to cover of impervious surfaces (Shuster et al. 2005, Chadwick et al. 2006). Associated development of road networks fragments habitat and inhibits movement across the landscape for turtles (Shepard et al. 2008). Mortality via vehicle strikes also ties into issues of adult mortality and juvenile recruitment (Sections 4.2 and 4.3). Furthermore, urbanization supports higher populations of mesopredators such as raccoons and skunks, primary predators of Wood Turtle adults, juveniles, and nests (Mitchell and Klemens 2000, Prange and Gehrt 2004).

4.1.2 Desired Future Condition

Sufficient habitat exists to support viable Wood Turtle populations.

4.1.3 10-Year Goal

Goal: Improve and maintain Wood Turtle habitat and habitat connectivity.

4.1.4 Strategies

The Wood Turtle Planning Team identified two strategies to progress toward the 10-Year Goal:

1) River System Management
2) Site Habitat.

4.1.5 Sub-strategies

The Wood Turtle Planning Team identified sub-strategies to focus each strategy, with the goal of developing targeted implementation activities with measurable outcomes. The strategies, sub-strategies, and how each issue is related to Wood Turtle habitat are presented in **Table 2**.

Development along the Southeast B River shoreline, MN. S. Carel

Table 2. Summary of Habitat Strategies, Sub-strategies, and Issues Related to Habitat

Strategy	Sub-strategy	Issues Related to Habitat						
		Agricultural Practices	Altered Hydrology	Forestry Practices	Invasive Species	Mineral Extraction	Recreation	Urbanization
River System Mgmt.	Protect habitat in key river stretches	x		x	x	x	x	x
	Increase terrestrial habitat connectivity	x		x		x	x	x
	Sustain free-flowing natural river systems	x	x	x				x
	Reduce agricultural overland and sub-surface runoff	x	x					
	Incorporate Wood Turtle needs into landscape scale planning efforts	x	x	x		x	x	x
Site Habitat	Identify, create, restore, and enhance nesting habitat		x	x	x	x	x	
	Identify, create, restore, and enhance foraging habitat	x		x	x			
	Identify, create, restore, and enhance hibernacula habitat for hatchlings	x	x				x	
	Improve site level management recommendations	x		x	x	x	x	x

Wood Turtle in native forest floor habitat. C. Hall

Wood Turtle in weedy corn field. C. Hall

4.2 ADULT MORTALITY, REMOVAL, AND SUB-LETHAL IMPACTS

4.2.1 Issue Statement

Loss of breeding adult Wood Turtles, particularly adult females, is a major issue for population viability. Wood Turtle populations rely on high adult survivorship to offset low recruitment early in life. Removal of even 2 to 3 individuals annually may result in extirpation of small, isolated populations (Congdon et al. 1993, Compton 1999). Adults may be lost from populations via mass mortality events, road mortality, predation, illegal collection, forestry and agricultural practices, environmental contamination, and disease. In some cases, impacts may be sub-lethal, but cumulative effects may contribute to increased mortality.

4.2.1-A: Adult Mass Mortality Events

Reports of mass mortality of adult Wood Turtles are of grave concern due to the potential for rapid loss of a large percentage of the breeding population. Since 2016, researchers have recorded unusually high observations of adult mortality (107 mortalities) for a Wood Turtle population in northeastern Minnesota (Berkeland et al. 2019, Crozier 2020). The cause of mortality is unknown. The majority of the dead Wood Turtle individuals were discovered each year in a specific river stretch, primarily in May, potentially suggesting a related event. Mass mortality of 12 Wood Turtles was reported in Pennsylvania (Jones et al. 2015). The cause of the Pennsylvania die-off was not determined, but also affected Bog Turtles (*Glyptemys muhlenbergii*). Mass mortality events in other freshwater turtles are linked with varying uncertainty to predation, infection, poisoning, drowning, poaching, and winterkill (Brooks et al. 1991, Catrysse et al. 2015).

Predation by otters during winter hibernation and spring sepsis caused mass mortality of a Canadian population of Snapping Turtles (*Chelydra serpentina*) (Brooks et al 1991). Predation was also responsible for mass mortality of a population of Pond Sliders (*Trachemys scripta*) in Illinois and was limited to nesting females of relatively smaller size (Tucker et al. 1999). Another event in Canada included 35 female Northern Map Turtles (*Graptemys geographica*); predation and boat strikes were ruled out due to intact shells, but the ultimate cause and specificity to females was unclear (Catrysse et al. 2015). Infectious disease following atypically cold weather resulted in mass mortality of an Eastern Box Turtle (*Terrapene carolina*) population in Kentucky, indicating an interactive effect with cooler and more variable climate (Agha et al. 2017). Studies of turtle populations following mass-die offs indicate that populations can be decimated quickly, and recovery may be slow (Brooks et al. 1991). Therefore, identification and mitigation of the cause of mass mortality in Wood Turtle populations is critical.

4.2.1-B: Road Mortality

Throughout their range, road mortality is identified as a significant cause of mortality for adult Wood Turtles (Akre and Ernst 2006; Jones et al. 2015). Seasonal movement of individuals may require crossing road networks to search for mates or nesting, foraging, and overwintering sites; modeling demonstrated that semi-terrestrial turtles with these traits are especially vulnerable to road mortality (Gibbs and Shriver 2002). Especially when natural habitat is lacking, roads with well-drained substrates attract Wood Turtles due to suitability for nesting (Buech et al. 1997; Cochrane et al. 2018), thereby serving as ecological traps (WDNR 2015). Consequently, proximity to roads may explain higher male to female sex ratios in some turtle populations (Steen et al. 2006).

In Minnesota, database records and local biologists indicate road mortality as a contributor to adult Wood Turtle mortality, though a recent study observed low mortality while monitoring road crossings (Berkeland et al. 2019, Crozier 2020). Road mortality is likely associated with loss of nesting habitat, increased development of road networks, and heavier traffic, and is closely related to the issue of habitat loss, fragmentation, and degradation described above.

4.2.1-C: Predation

Predation of adult Wood Turtles is recognized as a conservation concern (Jones et al. 2015). Elevated populations of mesopredators contribute to adult mortality via predation, though effects are more substantial for nests and young turtles (Section 4.3.1-A). Mesopredators such as raccoons and skunks occur at unnaturally high numbers in parts of the landscape due to a human-subsidized food supply (e.g. food waste, row crops), depressed populations of apex predators, and alterations to habitat (Mitchell and Klemens 2000). Direct predation of adults is rarely observed; however, mutilation or amputation is frequently observed and may have sub-lethal impacts (Harding and Bloomer 1979, Walde et al. 2003, Saumure et al. 2007, Moriarty and Hall 2014). One study noted that mutilated Wood Turtles were recaptured less frequently (Harding 1985). Studies in Minnesota also reported mutilation of adults and considered predation as a possible cause of adult deaths in a northeastern population (Cochrane et al. 2018). In northeastern Minnesota, Wisconsin, and Iowa, predation accounted for 75% of mortalities of telemetered Wood Turtles in which the cause of mortality could be determined (Lapin et al. 2019).

Snapping Turtle lurking at Wood Turtle nesting site. J. Naber

4.2.1-D: Illegal Collection

Though legally protected from commercial collection throughout its range, illegal take of Wood Turtles is a serious threat to populations. Historically Wood Turtles may have been collected as a food source, but the pet trade is currently considered the primary collection motive (Levell 2000, Walde 2007). Collection of Wood Turtles by humans for the pet trade may lead to local population crashes. Though often unconfirmed, suspected collections are frequently cited as causes of drastic declines. An Ontario population declined 70% following reported collections (Environment Canada 2016). Casual collection by landowners or recreationalists, however limited, can still have a significant effect on small, isolated populations (Environment Canada 2016). Commercial collection has not been documented in Minnesota, but the potential for single collection events to cause dramatic negative effects on populations remains a persistent threat.

4.2.1-E: Forestry and Agricultural Practices

Land use and land management practices from agricultural, forestry, and other activities are a source of adult mortality. Where agriculture is the dominant land use, Wood Turtles using agricultural fields may be crushed or mutilated by machinery (Saumure and Bider 1998, Environment Canada 2016). Similar death and injury may occur via forestry equipment, but direct observation is difficult and remains undocumented (Tingley and Herman 2008). Forestry access roads increase road density and open areas to off-highway vehicles. One adult Wood Turtle mortality was recorded in northeastern Minnesota on a small logging road (Crozier and Hamady 2018). Forestry roads may provide access to Wood Turtle areas, increasing the risk of collection by recreationalists. Several reports, based on personal communications, exist of mortality from recreational vehicles, and one study documented crushing of Wood Turtles by utility right-of-way maintenance equipment (Akre and Ernst 2006; Environment Canada 2016). Adult mortality from land management practices in Minnesota likely manifests differently in the northeastern and southeastern populations, where dominant land cover is primarily forest in the northeast and agriculture in the southeast.

4.2.1-F: Contaminants and Water Quality

Though poorly defined empirically, contaminants and poor water quality are a potential source of Wood Turtle mortality and sub-lethal impacts (Jones et al. 2015, Environment Canada 2016). Garber and Burger (1995) hypothesized Wood Turtles may be vulnerable to bioaccumulation because they are long-lived, and invertebrates comprise a significant part of their diet. Negative impacts of agricultural and industrial chemicals and poor water quality are reported for other turtle species (Mitchell and Klemens 2000, Shelby-Walker et al. 2009). For example, polychlorinated biphenyl (PCB) exposure can lead to higher deformity rates in juvenile turtles and increased mortality and slower growth (Ming-cheng Adams et al. 2016). Contaminants and poor water quality may disproportionately affect Wood Turtles during hibernation, because unlike many aquatic turtles, they remain aerobic and exposed to water flow during hibernation. Populations of Wood Turtles in New Jersey declined following application of pesticides in the 1950s and 60s according to Harding and Bloomer (1979). Additionally, low dissolved oxygen in slow-moving, eutrophic waters could affect hibernation success (Environment Canada 2016). Herbicides and pesticides sprayed during forest management and on crops may contaminate food resources of turtles. Effects of contaminants and poor water-quality may not be acute, but likely contribute sub-lethal impacts and must be considered a potential issue for Wood Turtles.

4.2.1-G: Disease

Disease is not currently considered an ongoing issue for the Wood Turtle, though the possibility for epidemics lurk as a potential threat. Disease is a potential explanation for mass mortality events, though no definitive evidence of infectious disease exists (Section 4.2.1-A). Disease is relatively prevalent in captive turtles but poorly understood in wild populations (Flanagan 2015). Pathogens cause mortality for other wild turtle populations in the northeastern U.S., such as *Ranavirus* for Box Turtles and an unidentified pathogen for Bog Turtles (Jones et al. 2015). Shell disease has been identified as an emerging threat to the recovery of the Western Pond Turtle (*Actinemys marmorata*) in Washington State (WDFW 2016, Woodburn et al. 2019). Disease in captivity reduces the viability of head starting as a recovery strategy, and spread of pathogens to wild populations poses serious risk for rapid loss of adult Wood Turtles (Mullin 2019). *Glyptemys* herpes and mycoplasmosis are other potential threats (Brown, personal communication). The threat of disease to Wood Turtle populations should therefore be taken very seriously.

4.2.2 Desired Future Condition

Adult mortality, removal, and sub-lethal impacts within populations are significantly reduced.

4.2.3 10-Year Goal

Goal: Identify and reduce adult mortality, removal, and sub-lethal impacts.

4.1.4 Strategies

The Wood Turtle Planning Team identified two strategies to progress toward the 10-Year Goal: 1) Reduce Human-Induced Mortality and 2) Reduce Natural/Unknown Mortality.

4.1.5 Sub-strategies

The Wood Turtle Planning Team identified sub-strategies to focus each strategy with the goal of developing targeted implementation activities with measurable outcomes. The strategies, sub-strategies, and how each issue is related to Wood Turtle adult mortality, removal, and sub-lethal impacts are presented in **Table 3**.

Wood Turtle with non-lethal injuries. J. Naber

Table 3. Summary of Adult Mortality, Removal, and Sub-lethal Impacts Strategies, Sub-strategies, and Issues related to these Strategies

Strategy	Sub-strategy	Issues Related to Adult Mortality, Removal, and Sub-lethal Impacts						
		Mass Mortality Events	Road Mortality	Predation	Illegal Collection	Forestry & Agricultural Practices	Contaminants & Water Quality	Disease
Human Induced Mortality	Reduce road mortality		X			X		
	Minimize risk of illegal take				X	X		
	Refine BMPs	X	X			X	X	
Natural/ Unknown Mortality	Effects of discrete flood events	X						
	Reduce predation	X		X				
	Develop protocols for testing for disease	X						X

4.3 JUVENILE RECRUITMENT

4.3.1 Issue Statement

Wood Turtle populations generally exhibit low levels of hatchling and juvenile recruitment. The age structure in many populations display high ratios of adults to young, although this is not atypical for most turtle species (Congdon et al. 1993). Though high mortality early in life is typical for the life-history strategy of the Wood Turtle, several factors contribute to lower than expected recruitment including nest and juvenile predation, poor nesting habitat, and altered hydrology. Additionally, many of the factors impacting adult mortality such as road mortality, land management practices, disease, and environmental contamination may play a role in low recruitment (Section 4.2.1).

4.3.1-A: Nest Depredation

High nest depredation rates are a major cause of low recruitment for the Wood Turtle. Inflated populations of mesopredators on the landscape (raccoon, fox, skunk, etc.) negatively impact nest success (Mitchell and Klemens 2000, Moriarty and Hall 2014). Other nest predators include flies of the families Phoridae and Sacrophagidae, which lay eggs in nest cavities and cause nest failure (Vogt 1981). Nests near roadsides are especially accessible to mesopredators and are depredated at close to 100% (WDNR 2016). Nest monitoring in one population in northeastern Minnesota, in a relatively unfragmented landscape, reported nest failure at 95%, with nests typically being depredated within hours of being laid (Cochrane et al. 2017a). Badgers were by far the most frequently observed species predating Wood Turtle nests in the study (85%), with raccoons, skunks, ravens/crows, and foxes comprising the remainder (Cochrane et al. 2017a, Berkeland et al. 2019). Even when nest cages were implemented, badgers learned to dig under the structures in the second year of the study.

Nest box protecting Wood Turtle nest. C. Hall

4.3.1-B: Hatchling and Juvenile and Predation

Hatchling and juvenile predation is also a major issue for the Wood Turtle for many reasons similar to nest depredation, though observation is more difficult. Predators of hatchlings and juveniles are similar to nest predators and include species such as chipmunks, numerous bird species, Snapping Turtle, and fish (Tuttle and Carroll 2005, Moriarty and Hall 2014, J. Naber, personal communication). Hatchling and juvenile predation is considered to be an issue throughout the Wood Turtle range (Harding and Bloomer 1979, Moriarty and Hall 2014, WDNR 2016). Survivorship of Wood Turtle hatchlings from emergence to winter in an Ontario population was 11% (assuming that the 24% of hatchlings that were lost all died), with most mortality due to predation (Paterson et al. 2012). Although high mortality of young is to be expected given the Wood Turtle's life history strategy, mortality due to predation was much higher for Wood Turtles compared to Blanding's Turtles (*Emydoidea blandingii*) (Paterson et al. 2012). Hatchling and juvenile predation is therefore a likely contributor to poor juvenile recruitment.

Wood Turtle hatchling in weedy riparian vegetation. G. Crozier

4.3.1-C: Poor Nesting Habitat

Poor quality and quantity of nesting habitat is contributing to low juvenile recruitment. Destruction of quality natural sites by humans occurred historically and continues today due to development and recreation along rivers (Section 4.1.1). Nesting sites are frequently overgrown due to invasive plants or lack of disturbance (Jones et al. 2015; Crozier and Hamady 2018). Moreover, there is a lack of natural nesting habitat on the landscape (Buech et al. 1997). More artificial than natural sites were identified and monitored in a study of a northeastern Minnesota population (Crozier and Hamady 2018). Turtles are frequently attracted to roadsides and gravel/sand pits to nest, which may act as ecological sinks. Over two years, a female in southeastern Minnesota was tracked to nesting sites in active or old agricultural fields (Hamady and Hall 2011). Additionally, the stress of longer and more perilous travel is a risk factor for both the nesting female and successful hatchlings. Prolonged searches for suitable habitat may delay nesting. Delayed nesting can result in nest failure, as eggs do not hatch below certain temperature thresholds, and late emerging hatchlings are unable to hibernate (Buech et al. 2004, WDNR 2016).

4.3.1-D: Altered Hydrology

Altered hydrology negatively affects Wood Turtle recruitment due to nest flooding, delayed nesting, and changes in the creation/maintenance of nesting habitat. Flooding in many parts of the Wood Turtle range is increasing in frequency, intensity, and duration, and is cited as a main contributor to nest failure (Spradling et al. 2010, Lenhart et al. 2013, WDNR 2016). Flooding was the primary cause of nest failure for populations of Wood Turtles monitored in Iowa (Spradling et al. 2010). A minority of nest sites in northeastern Minnesota failed due to flooding on the Northeast L River during a study, despite being identified as relatively flood safe, while many nest sites flooded on the Northeast D River during the same time period (Crozier 2020). Wood Turtle eggs are thought to have low viability beyond 24 hours of flooding based on expert observations and similar turtle species; 2 or more days of inundation are thought to be lethal (Kam 1994, Spradling et al. 2010, Lenhart et al. 2013). However, a field observation of a Wood Turtle nest inundated with water for 5 days found that some eggs hatched from the nest (Vraniak and Geller 2017).

Altered hydrology may additionally prohibit access to nesting sites until later in the season, delaying nesting and increasing risk of nest failure (Section 4.3.1-C). Natural river dynamics cause a shift in the location of suitable nesting habitat over time, potentially providing periods when nest depredation rates are reduced because predators have not yet found new nesting sites. Changes in hydrology may impact these dynamics, resulting in unnaturally high nest depredation rates from turtles using the same nesting site year after year, or being forced to use artificial sites like roadsides if suitable nesting sites are not being created or maintained on the river. Climate change will contribute to changes in hydrology.

4.3.2 Desired Future Condition

Recruitment occurs at self-sustaining levels.

4.3.3 10-Year Goal

Goal: Increase recruitment of juveniles into populations.

4.3.4 Strategies

The Wood Turtle Planning Team identified two strategies to progress toward the 10-Year Goal: 1) Nest Site Level and 2) Juvenile Survival.

4.3.5 Sub-strategies

The Wood Turtle Planning Team identified sub-strategies to focus each strategy with the goal of developing targeted implementation activities with measurable outcomes. The strategies, sub-strategies, and how each issue is related to Wood Turtle juvenile recruitment are presented in **Table 4**.

Table 4. Summary of Juvenile Recruitment Strategies, Sub-strategies, and Issues Related to Juvenile Recruitment

Strategy	Sub-strategy	Issues Related to Juvenile Recruitment			
		Nest Depredation	Hatchling & Juvenile Predation	Poor Nesting Habitat	Altered Hydrology
Nest site level	Reduce nest depredation	X		X	
	Reduce effects of flooding			X	X
	Enhance and protect nest habitat	X	X	X	X
	Protect nest sites from recreationalists	X	X	X	
Juvenile survival	Head starting	X	X	X	X
	Improve hatchling and juvenile habitat		X		X

Collecting eggs from nest site found in corn field. C.Hall

4.4 KNOWLEDGE GAPS

4.4.1 Issue Statement

Previous research and management efforts, combined with field expertise, inform ongoing work, and provide an excellent foundation for future Wood Turtle management in Minnesota. Although we know much about Wood Turtles, there are knowledge gaps that should be addressed to inform strategies and better address the overall conservation goal. Knowledge gaps range from analyzing existing data to researching or integrating new technologies or techniques. The Wood Turtle Planning Team identified knowledge gaps related to the previously identified issues of habitat, adult mortality, removal, sub-lethal effects, and juvenile recruitment. The Wood Turtle Planning Team also identified knowledge gaps related to population status and trends, survey protocols, and outreach. These categories are not identified as issues, but they represent foundational elements of conservation that require further study (**Table 5**).

4.4.2 Desired Future Condition

Acquire sufficient information to confidently make management decisions for Wood Turtle conservation.

4.4.3 10-Year Goal

Goal: Increase knowledge in key areas to improve effectiveness of the conservation strategies.

4.4.4 Strategies

For Knowledge Gaps, the Strategies are equivalent to the Issue/Research Need listed in **Table 5**.

4.4.5 Sub-Strategies

For Knowledge Gaps, the Sub-Strategies are equivalent to the Description listed in **Table 5**.

Performing Wood Turtle field work. M. Majeski

Table 5. Wood Turtle knowledge gaps identified by the Wood Turtle Planning Team

Issue/ Research Need	Knowledge Gap	Description
Habitat	Nest site selection	Research nest site selection, such as how new nesting sites are selected, to encourage use of good quality sites
	Foraging habitat selection	Research foraging habitat selection in forest, grassland, agricultural, and other land use types
	Hibernacula selection	Research hibernacula selection
	Forest management	Research how forests should be managed for Wood Turtles, particularly microhabitat requirements
	Invasive plant species	Research the negative and positive impacts of reed canary grass and other invasive plant species
	Movement	Research movement distances within and from rivers
	Climate change impact	Research climate change and river dynamics
Adult Mortality, Removal, and Sub-Lethal Effects	Unidentified mass mortality	Investigate cause and mitigation of unidentified mass mortality events
	Road mortality	Evaluate effectiveness of different road mortality prevention strategies
	Adult predation	Research predation of adults such as the impacts of maiming
	Illegal collection	Monitor for occurrence of illegal collection
	Contaminants and water quality	Research impact of environmental contaminants and water quality
Juvenile Recruitment	Head starting	Evaluate potential for head starting, including costs and benefits
	Nest protection	Evaluate effectiveness of different nest protection strategies
	Hatchling and juvenile threats	Research threats to hatchlings and juveniles
	Hatchling and juvenile habitat, diet, and movement	Research hatchling and juvenile habitat use, diet, and movement patterns
	Hatchling and juvenile hibernation	Research overwintering habitat use of hatchlings and juveniles
	Climate change and nesting	Research impact of climate change on nesting and juvenile recruitment
Population Status and Trends	Population viability	Assess and monitor population viability
	Population dynamics	Conduct and compare long-term studies of Wood Turtles in different watersheds to determine threats, rates of mortality, habitat use, etc.
	Distribution	Assess and monitor current distribution
	Genetic health	Collect genetic samples during surveys to evaluate the genetic viability of the population
Survey Protocols	eDNA	Evaluate effectiveness of eDNA in detecting presence of Wood Turtles within stream reaches
	Marking methodology	Evaluate effectiveness of marking techniques and standardize methods
	Survey protocol	Standardize survey protocols and evaluate need for regionally specific protocols
	Monitoring protocol	Standardize monitoring protocols for year to year comparison
	Turtle locating dogs	Evaluate effectiveness of turtle-locating dogs
	Genetic sample collection	Evaluate and standardize genetic sample collection methods
Outreach	Public engagement	Research methods to educate and engage public with Wood Turtles
	Public education	Assess strategies for public education

4.5 PARTNERSHIPS

4.5.1 Issue Statement

Wood Turtle research, monitoring, conservation, and recovery efforts are ongoing in Minnesota and throughout the Wood Turtle range in much of the Upper Midwest. Partnerships have been or are forming among agencies, non-governmental organizations, universities, and other stakeholders. These partnerships should be maintained and expanded upon to continue addressing Wood Turtle conservation within Minnesota and at a regional level.

4.5.2 Desired Future Condition

A network of partnerships exists that allows communication and coordination of information and management.

4.5.3 10-Year Goal

Goal: Enhance partnerships among Wood Turtle stakeholders in Minnesota and the Upper Midwest.

4.5.4 Strategies

The Wood Turtle Planning Team identified one strategy to progress toward the 10-Year Goal: Enhance Partnerships.

4.5.5 Sub-Strategies

The Wood Turtle Planning Team identified six sub-strategies to focus the strategy with the goal of developing targeted implementation activities with measurable outcomes (**Table 6**).

Table 6. Summary of Partnership Sub-strategies

Strategy	Sub-strategy
Enhance Partnerships	Maintain communication with existing partners
	Hold meetings with Wood Turtle experts to exchange information
	Look for opportunities to bring in new partners
	Investigate the feasibility of establishing an Upper Midwest monitoring program and database
	Pursue joint applications for funding within Minnesota and Upper Midwest
	Address data sensitivity

Typical Wood Turtle habitat, Northern Minnesota. J. Naber

5. IMPLEMENTATION PLAN

The Implementation Plan was developed collaboratively by the Wood Turtle Planning Team and Northeast and Southeast regional Work Groups. The Southeast and Northeast Work Groups used the strategies and sub-strategies developed by the Planning Team and completed worksheets detailing region-specific targeted implementation activities, milestones, tracking metrics, prioritization, and target start dates for each sub-strategy. The Work Group worksheets are included as Appendices. The central Minnesota Wood Turtle populations were included in the Northeast Work Group.

1. **Targeted Implementation Activities:**
   The targeted implementation activities are the implementation activities that address specific sub-strategies. These are countable projects, activities, services, or products that can be tracked as progress towards achieving the goals. Some activities may address more than one issue and achieve more than one goal.
2. **Milestones:**
   Milestones will assess progress of sub-strategies based on specific steps.
3. **Tracking Metrics:**
   Depending on the activity, tracking metrics may include a yes/in progress/no assessment of activity completion or specific quantities of activity outcomes.
4. **Prioritization:**
   Prioritization was assigned to sub-strategies based on regional Work Group expertise.
5. **Target Start Date:**
   A target start date within the next 10 years was assigned to sub-strategies based on regional Work Group expertise. Some sub-strategy activities are started or will be ongoing.

The Implementation Plan is presented in Table 8 through Table 20 and provides examples of targeted implementation activities and measurable outcomes for all sub-strategies. The full list of targeted implementation activities and measurable outcomes for each sub-strategy is included for each region in Appendices A and B. Key river stretches were also identified for both regions to help prioritize location of implementation activities. Descriptions of these key stretches are included in Appendices C and D.

Tracking performance toward targets is an important step to the Implementation Plan. Performance toward targets will be assessed every two years by the MN DNR by documenting completed activities according to a template comparable to the Conservation Partners Legacy Program Annual Report. After five years, work to date will be evaluated with potential for re-prioritization, timeline adjustment, and additional activities.

Implementation activities generally rely on grant funding. The Implementation Plan can be used to determine what activities need to be completed, how to prioritize, and which grants are applicable for specific activities. A list of potential and existing partners was compiled by the Wood Turtle Planning Team (**Table 7**). Partners are encouraged to use and participate in the Implementation Plan.

Partners can use the Implementation Plan to prioritize activities and apply for grant funding. Additionally, partners can track performance toward targets via the activity documentation assessment to be completed every two years.

Implementing this Conservation Plan will be challenging. There are many obstacles to achieving long-term conservation of Wood Turtles, from limitations in our knowledge about the species to the complexity of the systems Wood Turtles use, and practical limitations of funding and resources.

The Wood Turtle occurs at low densities so it is not easily detectable, and its distribution in Minnesota is not fully known. As with many wildlife research projects, Wood Turtle studies are often short-term from one population or a discrete area within one population. However, the riparian systems that Wood Turtles use are dynamic. Natural river fluctuations, natural terrestrial disturbance patterns, land use changes that disrupt natural processes, and climate change influence Wood Turtle populations and threats to these populations. Long-term, comprehensive studies are needed to understand how Wood Turtle populations, their habitat, and threats fluctuate spatially and temporally. However, these types of studies take large amounts of resources and long-term commitments to achieve, which can be difficult with short-term grant cycles and shifting agency priorities.

Wood Turtle surveys and data collection. J. LeClere

It is also important to acknowledge the vulnerability of the areas that Wood Turtles use. Riparian areas are very attractive to recreationalists and landowners, and the increase in recreation, development, and agriculture in areas supporting Wood Turtle populations is concerning. Some Wood Turtle populations occur in areas dominated by private land ownership, where implementing conservation measures may be very difficult. For Wood Turtle populations in areas dominated by public ownership, there is more opportunity for conservation efforts. However, conservation objectives are often not the top priority when making decisions about how to manage these lands.

In the face of these complexities and challenges, there are opportunities. Wood Turtle conservation will be most effective if biologists can leverage resources across various conservation and land management groups. There is potential to bring together a wide variety of specialists and stakeholders (biologists, hydrologists, watershed specialists, land managers, recreation specialists, law enforcement, conservation groups, private landowners, etc.) to combine resources and work collaboratively towards shared conservation goals. Taking a landscape-level systems approach to managing heathy watersheds will be the most effective way to conserve Wood Turtle populations over the long-term.

Wood Turtle captured while eating a worm. C. Hall

Table 7. List of potential and existing partners

Potential and Existing Partners	
Conservation Planning Specialist Group (CPSG) of IUCN	Tribal Governments
County Governments (e.g. Parks Departments)	Inter-Tribal Agencies and other Tribal Entities
Minnesota Board of Water and Soil Resources (BWSR)	Soil and Water Conservation Districts
Minnesota Department of Transportation	Trout Unlimited
Minnesota Land Trust	U.S. Department of Agriculture
Minnesota Zoo	U.S. Fish and Wildlife Service
MNDNR Divisions: Ecological and Water Resources, Parks & Trails, Fish & Wildlife, Forestry, Enforcement	U.S. Forest Service
National Park Service	Universities
Private Landowners	Watershed Management Organizations and Partnerships
The Nature Conservancy	Upper Midwest DNR agencies (WIDNR, IDNR, MIDNR)
Place A	Place C

Typical Wood Turtle riverbank habitat, MN. J. Naber

5.1 ISSUE: HABITAT

Table 8. Implementation Plan for the River System Management strategy

ISSUE: Habitat						
STRATEGY: River System Management						
Sub-strategy	**Region**	**Prioritization**	**Target Start Date**	**Example Targeted Implementation Activities**	**Example Milestones**	**Example Tracking Metrics**
Protect habitat in key river stretches	SE	High	1–2 years	Using available data, identify key areas for protection. Key areas may include sections of the river with large numbers of Wood Turtles, good habitat, important nest sites, or where there are existing protection efforts that can be expanded on. Consider conservation easements, natural area registry agreements, land acquisition, etc.	Compile known data for each main population to identify key river stretches for protection. Based on these data, recommendations are made on the highest priority river stretches and parcels for protection and potential protection options. At the highest priority sites, land is protected as opportunity allows.	# rivers evaluated # parcels protected
	NE	High	1–2 years			
Increase terrestrial habitat connectivity	SE	High	1–2 years	Identify ways to increase habitat connectivity. Consider techniques such as property acquisition, reforestation, removing invasive species, enforcement of shoreline ordinances, restoring high quality nesting habitat adjacent to the river, maintaining nesting, foraging, and overwintering habitats in close proximity in locations with no roads, etc.	Compile known data for each main population to identify barriers to movement and opportunities for increasing habitat connectivity. Based on these data, recommendations are made on the highest priority locations for reducing threats and increasing habitat connectivity and potential ways to address the issue. At the highest priority sites, habitat connectivity efforts are conducted.	# rivers evaluated # areas where connectivity is restored
	NE	Medium	3–5 years			
Sustain free-flowing natural river systems	SE	High	1–2 years	Identify ways to increase river connectivity. Consider techniques such as fish passage structures, terrestrial safe passage areas, removal of dams, restoring floodplains, etc.	Compile known data for each main population to identify locations with physical river connectivity issues. Based on these data, recommendations are made on the highest priority areas with river connectivity issues. At the highest priority sites, river connectivity efforts are conducted.	# rivers evaluated # areas where connectivity is restored
	NE	Medium	3–5 years			
Reduce agricultural overland and sub-surface runoff	SE	Medium	6–10 years	Identify targeted areas for improving practices to reduce runoff. Consider practices such as increased buffer zones and retention ponds/wetlands to hold runoff.	Participate in watershed planning efforts.	# planning efforts engaged
	NE	Low	6–10 years			
Incorporate Wood Turtle needs into landscape scale planning efforts	SE	High	1–2 years	Consider cumulative impacts of development and forest management projects on watershed health. Incorporate Wood Turtle habitat needs and threats to Wood Turtles into planning efforts. Incorporate climate change considerations in planning efforts.	Participate in or provide recommendations to the development of One Watershed One Plan (upcoming plans include several Wood Turtle rivers).	# guidance/planning efforts engaged
	NE	Medium	1–2 years			

Table 9. Implementation Plan for the Site Habitat strategy

ISSUE: Habitat						
STRATEGY: Site Habitat						
Sub-strategy	**Region**	**Prioritization**	**Target Start Date**	**Example Targeted Implementation Activities**	**Example Milestones**	**Example Tracking Metrics**
Identify, create, restore, and enhance nesting habitat	SE	High	3–5 years	Identify nesting sites and/or potential nesting sites using surveys and GIS data. Focus on natural nesting sites, important nesting sites, and important stretches of river for nesting. Restore or enhance nesting sites by removing invasive species and encroaching vegetation. Consider creating nesting habitat in areas that lack suitable habitat or have habitat connectivity issues.	Compile known data for each main population on nesting sites, potential nesting sites, turtle use, predation, and flooding risk. Conduct field surveys to identify key nesting sites, particularly natural sites. At the highest priority nesting sites, habitat improvement efforts are conducted.	# rivers evaluated # sites created, restored, or enhanced
	NE	High	1–2 years			
Identify, create, restore, and enhance foraging habitat	SE	High	1–2 years	Identify preferred foraging habitat using telemetry and/or GIS data. Manage for high quality native plant communities with abundant herbaceous forage. Maintain or enhance species and structural diversity as appropriate of the native plant community. Consider techniques such as artificial seeding, underplanting under-represented species, release of advanced regeneration, prescribed fire, and reducing invasive species.	Compile known data for each main population on potential foraging habitat. Based on these data, recommendations are made on the highest priority areas where foraging habitat could be enhanced. In the highest priority locations, conduct habitat improvement efforts.	# rivers evaluated # sites restored or enhanced
	NE	Low	6–10 years			
Identify, create, restore, and enhance hibernacula habitat	SE	Low	1–2 years	If lacking, place trees / large woody debris in the river adjacent to important nesting sites for overwinter habitat for hatchlings. Discuss trail maintenance with DNR Parks and Trails. Recommend leaving fallen trees in the river as much as possible.	Nesting sites where habitat enhancement work has occurred also has adjacent overwintering habitat for hatchlings. Recommendations provided to DNR Parks and Trails.	# sites where management activities occurred # outreach efforts to DNR Parks and Trails
	NE	Low	6–10 years			
Improve site level management recommendations	SE	High	1–2 years	Revise forest management recommendations for Wood Turtles using results from the cSWG projects as well as other sources of information. Develop BMPs for Wood Turtles in SE MN. Work with environmental review staff and MNDOT to revise recommendations for development and road projects.	Forest management recommendations are revised and BMPs developed (i.e., DNR guidance document). Environmental review recommendations for Wood Turtles are revised (i.e., DNR environmental fact sheet). Guidance documents are distributed to land managers (DNR staff, county land departments, USFS, private landowners, etc.).	# documents completed
	NE	High	1–2 years			

5.2 ISSUE: ADULT MORTALITY, REMOVAL, AND SUB-LETHAL IMPACTS

Table 10. Implementation Plan for the Human Induced Mortality strategy

ISSUE: Adult Mortality, Removal, and Sub-Lethal Impacts						
STRATEGY: Human Induced Mortality						
Sub-strategy	**Region**	**Prioritization**	**Target Start Date**	**Example Targeted Implementation Activities**	**Example Milestones**	**Example Tracking Metrics**
Reduce road mortality	SE	Medium	3–5 years	Using available data, identify locations with road mortality issues or potential issues. Work with MNDOT and county land departments to identify ways to reduce road mortality in problem areas. Consider techniques like safe passage benches, installing road barriers, turtle crossing signs, reducing the attractiveness of roads, creating alternative nesting habitat in the vicinity, public information announcements, etc.	Compile known data for each main population to identify areas with road mortality and potential road mortality issues. At the highest priority sites, road mortality surveys are conducted and/or efforts are made to modify road crossings in collaboration with the appropriate road authority.	# rivers evaluated # areas with road crossing modifications
	NE	High	1–2 years			
Minimize risk of illegal take	SE	Medium	1–2 years	Wood Turtle experts and the DNR Endangered Species Coordinator should weigh the risks vs. benefits of involving local citizens in the protection of local Wood Turtle populations. Come to a decision about if local citizens could be recruited to help with Wood Turtle conservation efforts and to watch for poachers. Educate citizens about not taking turtles home and the concerns about rare turtle populations. Provide conservation officers with the location of significant Wood Turtle populations so they can watch out for poachers.	A decision is made about how to engage citizens in Wood Turtle conservation. Conservation officers are provided information on Wood Turtle populations.	# outreach efforts to public # outreach efforts to conservation officers
	NE	High	1–2 years			
Refine BMPs	SE	Medium	3–5 years	Revise forest management recommendations for Wood Turtles using results from the cSWG projects as well as other sources of information. Develop best management practices for sand and gravel mining operations. Determine adequate buffer widths for agricultural fields and livestock. Assess distance traveled by radio-tagged turtles to develop preferred buffer widths.	Forest management recommendations are revised (i.e., DNR forest management guidelines). BMPs are developed for mining operations. Buffer widths are determined.	# BMP recommendations revised/developed
	NE	High	1–2 years			

Table 11. Implementation Plan for the Natural/Unknown Mortality strategy

ISSUE: Adult Mortality, Removal, and Sub-Lethal Impacts						
STRATEGY: Natural/Unknown Mortality						
Sub-strategy	**Region**	**Prioritization**	**Target Start Date**	**Example Targeted Implementation Activities**	**Example Milestones**	**Example Tracking Metrics**
Effects of discrete flood events	SE	High	1–2 years	Utilize telemetry and/or marked turtles to assess impacts of flood events on turtles. Identify potential backwater areas or eddies where turtles could escape the flood waters and ultimately return to home range.	Conduct study.	# important backwater areas identified
	NE	Low	6–10 years			
Reduce predation	SE	Medium	3–5 years	Assess the impacts of predation on the population. Develop recommendations to reduce adult mortality.	Conduct study.	# recommendations developed
	NE	Medium	6–10 years			
Develop protocols for testing for disease	SE	Low	3–5 years	Collect dead turtles found during survey activities and submit for testing when feasible. Collect samples from live turtles (sick and healthy individuals) for testing.	When large die-offs occur, samples are collected and tested within 1-2 years of the event.	# samples collected
	NE	High	1–2 years			

5.3 ISSUE: JUVENILE RECRUITMENT

Table 12. Implementation Plan for the Nest Site Level strategy

ISSUE: Juvenile Recruitment						
STRATEGY: Nest Site Level						
Sub-strategy	**Region**	**Prioritization**	**Target Start Date**	**Example Targeted Implementation Activities**	**Example Milestones**	**Example Tracking Metrics**
Reduce nest depredation	SE	High	1–2 years	Using available data, identify locations where nest depredation is a problem or is likely a problem. Conduct field surveys or use remote cameras to determine the extent of the problem. Protect nests from depredation using techniques such as nest cages and electric fences. Consider if predator control could be a useful technique.	Compile known data for each main population on nest depredation, predators, and the most important nesting sites. Based on these data, recommendations are made on the most critical areas for protecting nests from depredation. Consider prioritizing locations where nesting habitat improvement efforts have occurred. At the highest priority areas, efforts are made to reduce nest depredation.	# rivers evaluated # nests or sites protected # successful nests (hatchlings)
	NE	High	1–2 years			
Reduce effects of flooding	SE	High	1–2 years	Using available data, identify locations where nest flooding is an issue or a potential issue. Create hydrologic models to predict flooding risk and assess impacts of climate change on flooding. On nest sites with flooding concerns, consider expanding the nest site to include additional flood-safe habitat.	Compile known data for each main population on nest flooding and turtle use. At the highest priority sites, expand nesting sites into flood-safe areas where feasible.	# rivers evaluated # sites expanded
	NE	Medium	3–5 years			
Enhance and protect nest habitat	SE	High	1–2 years	Identify high priority nesting sites (with an emphasis on natural sites) and monitor turtle use, predation rates, and flooding. Restore and enhance the habitat quality on the highest priority nesting areas. Identify locations that are population sinks in terms of high nest failure rates (roadsides, agricultural fields, active gravel pits, etc.). Determine if there are ways to reduce turtle use of these areas, create nesting habitat nearby, or re-direct turtles to higher quality areas. Identify stretches of river where good nesting habitat may be lacking, particularly where turtles nest on roads. Consider creating nesting habitat.	Compile known data for each main population on high priority nesting sites, stretches of river that lack nesting habitat, or nesting sites that are at high risk of development. Set up long-term monitoring sites to monitor turtle nesting, predation, flooding, and hatching rates. At the highest priority areas, nesting habitat is enhanced or protected as feasible.	# rivers evaluated # long-term monitoring sites # successful nests (hatchlings)
	NE	High	1–2 years			
Protect nest sites from recreationalists	SE	Low	3–5 years	Identify high priority nesting sites that are used by recreationists. Conduct field surveys or use remote cameras to determine the extent of the problem. Reduce recreational pressure at high priority sites. Block access to nesting sites, consider seasonal closures, contact COs about illegal activity.	Compile known data for each main population on locations where recreation is a problem. At the highest priority sites, efforts are made to reduce recreation on nest sites.	# rivers evaluated # sites protection efforts
	NE	Medium	3–5 years			

Table 13. Implementation Plan for the Juvenile Survival strategy

ISSUE: Juvenile Recruitment						
STRATEGY: Juvenile Survival						
Sub-strategy	**Region**	**Prioritization**	**Target Start Date**	**Example Targeted Implementation Activities**	**Example Milestones**	**Example Tracking Metrics**
Head starting	SE	High	1–2 years	Identify areas with high potential for successful establishment. Remove eggs from wild nests: incubate eggs and then release young shortly after hatching versus raise ex-situ for period of time (1-2 years) and then release.	Compile known data for each main population on relevant to potential headstart establishment. Based on these data, recommendations are made on the highest priority areas for headstarting. Release headstarts at priority areas.	# rivers evaluated # headstarts successfully reared and released # headstarts surviving in wild after X number of years
	NE	Low	6–10 years			
Improve hatchling and juvenile habitat	SE	Medium	6–10 years	Identify potential hatchling and juvenile habitats. Assess if these habitats could be enhanced, such as removing invasive species.	Compile known data on hatchling and juvenile habitat requirements. Determine locations where habitat could be enhanced. Focus on areas with high quality nesting. Conduct habitat management.	# rivers evaluated # sites managed
	NE	Low	6–10 years			

5.4 ISSUE: KNOWLEDGE GAPS

Table 14. Implementation Plan for the Habitat strategy

ISSUE: Knowledge Gaps						
STRATEGY: Habitat						
Sub-strategy	**Region**	**Prioritization**	**Target Start Date**	**Example Targeted Implementation Activities**	**Example Milestones**	**Example Tracking Metrics**
Understand benefits and consequences of reed canary grass and other invasives	SE	Low	6–10 years	Determine habitat selection or avoidance in areas infested with invasive species. Determine how much impact invasive species may have on affecting habitat.	Establish research partners Acquire funding	Project conducted
	NE	Medium	6–10 years			
Understand foraging habitat selection in forest, grassland, agriculture, and other land use	SE	Medium	3–5 years	Analyze the cSWG telemetry data to determine foraging habitat selection in relationship to habitat availability. Conduct field surveys to quantify the vegetation characteristics in heavily used foraging areas (amount of downed woody debris, herbaceous vegetation, canopy closure, etc.). Use telemetry to assess habitat use in rivers with no habitat information.	Establish research partners Acquire funding	Project conducted
	NE	High	1–2 years			
Better understand how habitat could be managed, particularly for microhabitat needs	SE	High	6–10 years	Research project or monitoring in an adaptive mgmt. framework. Develop protective strategies for agricultural areas used by turtles. Determine important habitat characteristics that could be managed for during typical forest management activities. Determine how turtles respond to different forest management practices.	Establish research partners Acquire funding	Project conducted
	NE	Medium	3–5 years			
Better understand nesting site selection	SE	High	3–5 years	Compare use of created sites vs. sites Wood Turtles traditionally have used. Determine what kinds of created sites will they prefer over traditionally used sites. Assess if size of site should be factored into the research on nest site effectiveness. Identify characteristics of successful nest sites, nest site fidelity, and the importance of staging habitat.	Establish research partners Acquire funding	Project conducted
	NE	Medium	3–5 years			
Better understand hibernacula selection	SE	Low	6–10 years	Using the cSWG telemetry data, collect and analyze data to quantify river and habitat features at hibernacula sites. Assess if hibernacula sites may be limiting. If so, make recommendations on how to better manage for hibernacula sites.	Establish research partners Acquire funding	Project conducted
	NE	High	1–2 years			
Research on movement distances	SE	High	3–5 years	Use cSWG data to assess movements up and downstream on the river, movements from the river onto land, determine home range, and examine typical movement patterns between the hibernacula site, nesting site, and foraging sites. Examine the cSWG data to see if there appear to be differences in turtle habitat use and movement patterns between the main river and tributaries. From this, determine if more telemetry data is needed to quantify habitat use and movement patterns of turtles in smaller tributaries.	Establish research partners Acquire funding	Project conducted
	NE	High	1–2 years			
Understand climate change and river dynamics	SE	High	6–10 years	Establish long-term monitoring sites to assess flooding of nest sites. Create hydrologic models to assess the impacts of climate change and changes in hydrology on nesting habitat availability. On nest sites with flooding concerns, consider expanding the nest site to include additional habitat that is typically flood-safe.	Establish research partners Acquire funding	Project conducted
	NE	Medium	6–10 years			

Table 15. Implementation Plan for the Adult Mortality strategy

ISSUE: Knowledge Gaps						
STRATEGY: Adult Mortality						
Sub-strategy	**Region**	**Prioritization**	**Target Start Date**	**Example Targeted Implementation Activities**	**Example Milestones**	**Example Tracking Metrics**
Investigate unidentified mortality events (e.g. disease)	SE	Low	1–2 years	Consult with the National Wildlife Health Center and other disease labs regarding proper protocols, such as where should samples be sent, how to collect and store samples, etc. Establish a protocol.	Samples are sent for testing within 1-2 years of a large mortality event	Project conducted
	NE	High	1–2 years	Conduct research on possible causes of the mortality event (water level changes, etc.). Conduct literature search for information related to turtle mortality in general.	Establish research partners Acquire funding	
Effectiveness of different road mortality prevention strategies	SE	Medium	1–2 years	Experiment with different barrier designs, materials, and ways to deal with private lands to see what is most effective.	Establish research partners	Project conducted
	NE	Medium	3–5 years	Conduct research on dangerous crossings to see what characteristics are associated with these crossings.	Acquire funding	
Research cause of injury and mortality of adults (i.e. predation, mowing)	SE	Medium	3–5 years	Determine the importance of different causes of adult mortality and injury.	Establish research partners Acquire funding	Project conducted
	NE	Low	6–10 years			
Monitor if illegal collection is occurring	SE	Medium	1–2 years	Assess sites for vulnerability to collecting. Monitor priority sites with game cameras.	Establish research partners Acquire funding	Project conducted
	NE	Low	6–10 years			
Research on impacts of environmental contaminants	SE	Low	3–5 years	Collect environmental and turtle samples to assess presence/levels of selected chemicals.	Establish research partners Acquire funding	Project conducted
	NE	Low	6–10 years			

Table 16. Implementation Plan for the Juvenile Recruitment strategy

ISSUE: Knowledge Gaps						
STRATEGY: Juvenile Recruitment						
Sub-strategy	**Region**	**Prioritization**	**Target Start Date**	**Example Targeted Implementation Activities**	**Example Milestones**	**Example Tracking Metrics**
Effectiveness of different nest protection strategies	SE	High	1–2 years	Additional testing of electric fences is needed. Install electric fences on several more sites to confirm they are effective in different situations (particularly sites with high predation or different types of predators).	Establish research partners	Project conducted
	NE	High	1–2 years	Compare depredation and productivity rates of protected vs. control nests. Refine our estimates of depredation rates for unprotected nests.	Acquire funding	
Research on threats to hatchlings and juveniles	SE	Medium	3–5 years	Using telemetry, track hatchlings and juveniles to determine potential threats.	Establish research partners	Project conducted
	NE	Medium	3–5 years	Necropsy deceased juveniles to determine cause of death when feasible.	Acquire funding	
Research hatchling and juvenile habitat use, diet, and movement patterns	SE	High	3–5 years	Using telemetry, examine habitat use and movement patterns of hatchlings and juveniles.	Establish research partners Acquire funding	Project conducted
	NE	High	3–5 years			
Overwintering habitat use of hatchlings and juveniles	SE	Medium	3–5 years	Using telemetry, determine characteristics of overwintering sites of hatchlings and juveniles. Determine if overwintering habitat is limiting.	Establish research partners Acquire funding	Project conducted
	NE	Low	6–10 years			
Research impact of climate change on nesting and juvenile recruitment	SE	High	1–2 years	Determine habitat use of juveniles, and whether they are moved downstream after flooding events and if there is correlation between displacement and extent of flooding.	Establish research partners Acquire funding	Project conducted
	NE	Medium	6–10 years	Install water level loggers at nest sites to measure water elevations and flood duration. Use hydrologic models to predict how climate change will affect the availability of nesting habitat and flooding of nest sites.		

Table 17. Implementation Plan for the Survey Protocol strategy

ISSUE: Knowledge Gaps						
STRATEGY: Survey Protocols						
Sub-strategy	**Region**	**Prioritization**	**Target Start Date**	**Example Targeted Implementation Activities**	**Example Milestones**	**Example Tracking Metrics**
Effectiveness of eDNA surveys	SE	High	1–2 years	Determine best timing of water collection (i.e. when would eDNA be most concentrated). Develop a procedure specific to Minnesota for using eDNA to detect Wood Turtles (i.e., ensure known sequences can be matched to our test samples). Collect water samples at sites with both known populations of varying abundances (to document detectability) and sites with no known populations (to assess presence/absence).	Establish research partners Acquire funding	Project conducted
	NE	Low	6–10 years			
Evaluate effectiveness of marking techniques and standardize methods used	SE	Medium	3–5 years	Using existing data, compare error rates in identifying recaptures using different marking methods. Develop a standard marking protocol by river.	Compile data Analyze data	Recommendations on standard marking protocol
	NE	Low	6–10 years			
Standardizing survey protocols	SE	High	3–5 years	Describe methods already being utilized in MN surveys during different seasons and locations or using various approaches (i.e., watercraft, hiking, cameras, dogs, etc.). Describe conditions under which each approach is optimal and note conditions that prevent efforts (i.e. vegetation height, water levels, temperature, etc.). Develop protocols for assessing occupancy of under-surveyed rivers and for monitoring population contraction and expansion.	Protocol drafted and reviewed by turtle researchers within/outside DNR Datasheets updated based on standardized protocol	Protocol finalized
	NE	Medium	3–5 years			
Standardizing monitoring protocols	SE	Medium	6–10 years	Assess if the monitoring protocol developed for the Northeast L River is effective for the other rivers in the northeast. If not, work with U of M to modify the protocol for use on other rivers. Work towards a standard or comparable protocol for the NE and SE populations. Work towards a standard or comparable protocol for the region (WI, IA, MI, MN). Create a statewide database for MN Wood Turtle monitoring data (including a photo database).	A standard protocol is finalized (could be river specific) A database is created for-Minnesota	Protocol finalized for X number of locations Database is created
	NE	High	3–5 years			
Effectiveness of turtle dogs	SE	High	3–5 years	Pursue funding to train a dog specifically for detecting Wood Turtles (i.e. LCCMR funding: MN Zoo). Continue to assess working with local or regional handlers. Test dog at locations with known healthy turtle populations (or sites with radio-tagged turtles).	Acquire a trained dog, or acquire a dog and train it to detect Wood Turtles Follow up on progress of dog ability to locate Wood Turtles Radio-tagged Wood Turtles are independently and consistently detected by dog without guidance by handler	Dog used for surveys Effectiveness of dogs assessed
	NE	Low	6–10 years			
Evaluate and standardize genetic sample collection methods	SE	High	1–2 years	Conduct literature review of sampling protocol a. what: blood samples, tissue, shell shavings, etc. b. where: caudal vein, nuchal sinus cavity, or other locations. Test sampling options on MN turtles. Develop standardized approach for collecting and analyzing samples based on testing results.	Literature compiled on what samples to collect and where to collect them Sampling methods tested on turtles (not necessarily Wood Turtles) Standardized approach drafted and reviewed by turtle researchers and geneticists	Protocol finalized
	NE	Low	6–10 years			

Table 18. Implementation Plan for the Population Status and Trends strategy

ISSUE: Knowledge Gaps						
STRATEGY: Population Status and Trends						
Sub-strategy	**Region**	**Prioritization**	**Target Start Date**	**Example Targeted Implementation Activities**	**Example Milestones**	**Example Tracking Metrics**
Assess and monitor population viability	SE	High	6–10 years	Set up long-term monitoring sites on each main population. Monitor each population every 5 years. Assess relative abundance, adult sex ratio, juvenile-adult ratio, survivorship, and age class structure.	Long-term monitoring sites are established on each main population Baseline data is collected on each main population Population modeling efforts continue with additional data	# rivers with long-term monitoring sites established # sites re-surveyed every 5 years
	NE	High	3–5 years			
Assess and monitor current distribution	SE	High	1–2 years	Determine the highest priority under-surveyed areas. Focus on rivers with good habitat and under-surveyed areas near known populations. Consider re-surveying old or questionable NHIS records to determine if populations exist in those areas. Determine the highest priority areas for monitoring contraction and expansion of each main population. Conduct occupancy surveys at regular intervals in the highest priority areas.	The highest priority under-surveyed rivers are surveyed Occupancy monitoring is initiated to assess population expansion or contraction on each main population	# under-surveyed river stretches surveyed # populations surveyed for expansion/contraction
	NE	High	1–2 years			
Take genetic samples during surveys to evaluate population genetic viability	SE	High	3–5 years	Determine if there are rivers in which assessing genetic health is a priority. Consider using genetic samples to confirm that populations are isolated from each other. Determine the protocol for collecting genetic samples, storage of samples, and number of samples needed.	The highest priority rivers are assessed for genetic health Sampling protocol developed	# priority rivers for sampling # populations sampled
	NE	Medium	6–10 years			
Long-term study of population dynamics and mortality	SE	*	*	Conduct a long-term study of adult Wood Turtles to determine causes of death and rates of mortality to better understand relative threats to turtles. Compare Wood Turtle populations in different landscapes and watersheds.	Establish research partners Acquire funding	Project conducted
	NE	High	3–5 years			

Table 19. Implementation Plan for the Outreach strategy

ISSUE: Knowledge Gaps						
STRATEGY: Outreach						
Sub-strategy	**Region**	**Prioritization**	**Target Start Date**	**Example Targeted Implementation Activities**	**Example Milestones**	**Example Tracking Metrics**
Research ways to educate and engage public with Wood Turtles	SE	Low	6–10 years	Determine what has been effective outreach for other at-risk species. Conduct and assess the effectiveness of outreach programs, news releases, fundraising efforts, etc.	Complete review of public outreach strategies	# outreach efforts to public conducted
	NE	Low	6–10 years			
Strategies for public education	SE	Low	6–10 years	Determine strategies for educating private landowners about what they can do on their lands to help Wood Turtles.	Develop strategies	# outreach efforts to private landowners conducted
	NE	Medium	6–10 years			

**To be considered for the southeast region in following 10-year plan period.*

5.5 ISSUE: PARTNERSHIPS

Table 20. Implementation Plan for the Enhance Partnerships strategy

ISSUE: Partnerships						
STRATEGY: Enhance Partnerships						
Sub-strategy	**Region**	**Prioritization**	**Target Start Date**	**Example Targeted Implementation Activities**	**Example Milestones**	**Example Tracking Metrics**
Maintain communication with existing partners	SE	High	1–2 years	Conduct an annual pre-field season conference call to discuss upcoming field season activities and topics of interest. Keep partners informed by sharing reports, pertinent data, and project proposals.	Annual pre-field season coordination meeting occurs	# annual meetings conducted
	NE	High	1–2 years			
Hold meetings with Wood Turtle experts to exchange information	SE	Medium	1–2 years	Collaborate with partners to organize a regional Wood Turtle workshop.	Workshop is held	# workshops conducted
	NE	Medium	3–5 years			
Look for opportunities to bring in new partners	SE	Medium	1–2 years	Pursue opportunities to engage with potential partners. Reach out to local conservation groups to explore potential collaborations.	Opportunities to connect with new partners occurs	# new partnerships formed
	NE	Medium	3–5 years			
Investigate the feasibility of establishing an Upper-Midwest monitoring program and database	SE	Medium	3–5 years	Coordinate with partners to discuss the feasibility of a regional monitoring program. Identify a project lead to oversee data management.	Discussions with regional partners occurs	# meetings conducted
	NE	Low	6–10 years			
Pursue joint applications for funding within Minnesota and Upper Midwest	SE	High	1–2 years	Work with partners to identify potential sources of funding. Apply for grants, cooperatively with partners when possible. Pursue internal funding sources so that a consistent source of funds for plan implementation are available.	Grant proposals are submitted	# grants applied for
	NE	High	1–2 years			
Address data sensitivity	SE	High	1–2 years	Discuss the sensitivity of Wood Turtle data with land managers (i.e., county land managers, DNR land managers) and project partners. Data are stored in a secure location. Define how data is shared without compromising the population.	Develop data accessibility and sharing plan	# outreach efforts conducted
	NE	Medium	3–5 years			

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